Third Five-Year Review Report
Harbor Island Superfund Site
Seattle, Washington

Prepared for

U.S. Environmental Protection Agency
Region 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101

Approved by

_____ _____

Daniel D. Opalski, Director — Date
Office of Environmental Cleanup
U.S. EPA Region 10

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(Note: Chapter 6 tables are located in a separate section at the end of this report.)

ACRONYMS AND ABBREVIATIONS

AGB	abrasive grit blast
AKART	all known, available, and reasonable technologies
AOC	Administrative Order on Consent
ARARs	Applicable or relevant and appropriate requirements
AWQC	ambient water quality criteria
BP	BP West Coast Products
CAA	Clean Air Act
CAP	Cleanup Action Plan
CD	Consent Decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	chemicals of concern
EBAP	Elliott Bay Action Program
Ecology	Washington Department of Ecology
ENR	Enhanced Natural Recovery
EPA	U.S. Environmental Protection Agency
EPAECAO	USEPA Environmental Criteria and Assessment Office
ESD	Explanation of Significant Differences
EW-OU10	East Waterway Operable Unit
EWW	East Waterway
Fish Coordination Plan	Tribal Fishing Coordination Plan
FS	Feasibility Study
HWM	Hazardous Waste Management
ICs	institutional controls
IRIS	Integrated Risk Information System
KM	Kinder Morgan Liquid Terminals
LDW	Lower Duwamish Waterway
LNAPL	light non-aqueous phase liquid
LSS-OU7	Lockheed Shipyard Sediments Operable Unit
LU-OU3	Lockheed Upland Operable Unit
MLLW	Mean Lower Low Water
mS/cm	millisiemens/centimeter
MTCA	Model Toxics Control Act

ACRONYMS AND ABBREVIATIONS (CONTINUED)

NAAQS	National Ambient Air Quality Standards
NAPL	non-aqueous phase liquid
NCP	National Contingency Plan
NPL	National Priorities List
NRWQC	National Recommended Water Quality Criteria
NWQC HH	National Recommended Water Quality Criteria, Human Health
O&M	Operations and Maintenance
OMMP	Operations, Maintenance, and Monitoring Plan
OU	operable unit
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PRP	Potentially Responsible Party
PSAPCA	Puget Sound Air Pollution Control Agency
RA	remedial action
RAOs	Remedial Action Objectives
RD	Remedial Design
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RNA	Restricted Navigation Area
ROD	Record of Decision
RRO	Residual Range Organics
S&G-OU1	Soil and Groundwater Operable Unit
SAP	Sampling Analysis Plan
Shell	Shell Oil Products
SMAs	Site Management Areas
SMS	Sediment Management Standards
SQS	sediment quality standards
SRI	supplemental remedial investigation
SVE	soil vapor extraction
SVOCs	semivolatile organic compounds
SWM	Solid Waste Management
TBT	tributyltin

ACRONYMS AND ABBREVIATIONS (CONTINUED)

TCLP	toxicity characteristic leaching procedure
TF-OU2	Tank Farms Operable Unit
TPH	total petroleum hydrocarbons
TPH-G	total petroleum hydrocarbons-gasoline
TSCA	Toxic Substances Control Act
TSS-OU9	Todd Shipyards Sediments Operable Unit
USACE	U.S. Army Corps of Engineers
USCG	United States Coast Guard
VOCs	volatile organic compounds
WA PCS	State of Washington Petroleum-Contaminated Soil
WPCA	Water Pollution Control Act
WRA	Water Resources Act
WWCA	Water Well Construction Act
WW-OU8	West Waterway Operable Unit

FIVE-YEAR REVIEW SUMMARY FORM

SITE IDENTIFICATION

Site name *(from WasteLAN)*: Harbor Island

EPA ID *(from WasteLAN)*:

Region: 10	**State: WA**	**City/County: Seattle/King**

SITE STATUS

NPL status: ☒ Final ☐ Deleted ☐ Other (specify)

Remediation status (choose all that apply): ☒ Under Construction ☒ Operating ☐ Complete

Multiple OUs?* ☒ YES ☐ NO	**Construction completion date:** N/A

Has site been put into reuse? ☒ YES ☐ NO Port of Seattle container terminal.

REVIEW STATUS

Lead agency: ☒ EPA ☐ State ☐ Tribe ☐ Other Federal Agency _____

Author name: Ravi Sanga

Author title: Remedial Project Manager	**Author affiliation: USEPA Region 10**

Review period: May 2009 to September 2010

Date(s) of site inspection:

Type of review:
☒ Post-SARA ☐ Pre-SARA ☐ NPL-Removal only
☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead
☐ Regional Discretion

Review number: ☐ 1 (first) ☐ 2 (second) X 3 (third) ☐Other (specify) _____

Triggering action:
☐ Actual RA On-site Construction at OU ☐ Actual RA Start at OU#____
☐ Construction Completion ☒ Previous Five-Year Review Report
☐ Other (specify)

Triggering action date *(from WasteLAN)*: September 28, 2005

Due date *(five years after triggering action date)*: September 28, 2010

Notes: * "OU" refers to operable unit.

Review period should correspond to the actual start and end dates of the Five-Year Review in WasteLAN.

1. INTRODUCTION

The purpose of the five-year review is to determine whether the remedy at a site is protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in Five-Year Review reports. In addition, Five-Year Review reports identify issues found during the review, if any, and identify recommendations to address them.

The Agency is preparing this Five-Year Review report pursuant to CERCLA §121 and the National Contingency Plan (NCP. CERCLA §121 states:

> *If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented. In addition, if upon such review it is the judgment of the President that action is appropriate at such site in accordance with Section [104] or [106], the President shall take or require such action. The President shall report to the Congress a list of facilities for which such review is required, the results of all such reviews, and any actions taken as a result of such reviews.*

The Agency interpreted this requirement further in the NCP at 40 Code of Federal Regulations (CFR) §300.430(f)(4)(ii), which states:

> *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selected remedial action.*

The U.S. Environmental Protection Agency (EPA, Region 10, and the Washington Department of Ecology (Ecology) conducted the Five-Year Review of the remedy implemented at the Harbor Island Superfund Site in Seattle, Washington. This review was conducted by the Remedial Project Managers (RPMs) for the entire site from September 2009 through September 2010. This report documents the results of the review.

This is the third site-wide five-year review for the Harbor Island site. The triggering action for this statutory review is the Second Five-Year Review Report dated September 28, 2005. The five-year review is required due to the fact that hazardous substances, pollutants, or contaminants remain at the site above levels that allow for unlimited use and unrestricted exposure.

Other related Harbor Island documents may be found on the Web at: <www.epa.gov/r10earth>; click on A-Z Subject Index; Click on “H” for Harbor Island Superfund Site.

2. SITE CHRONOLOGY

2.1 OPERABLE UNIT (OU) IDENTIFICATION

The Harbor Island Site began as an investigation of a secondary lead smelter located on the island. The distribution of lead and other metals occurred over the entire island and, therefore, the investigation became island-wide. After the investigation began, it was realized that creating separate operable units (OUs) would be advantageous for managing the cleanup processes (see Figures 2-1 and 2-2 located at the end of this document). Investigations began site wide for soil and groundwater contamination. The Lockheed Upland OU was soon established to facilitate a cleanup of a particular land parcel on a separate time and management schedule. The investigation of contaminated sediments both nearshore and in Elliott Bay were separated and added as new OUs. Part of the island investigation included petroleum tank farms, and management of these parcels was given to Ecology as the Tank Farms OU. The OU number is a database number used to identify each of the OUs and is for reference only as the official OU name does not include a number. The following is a list of the operable units in current use:

OU No.	Description
N/A	Harbor Island Lead Site; Initial Island-Wide Investigation
01	Soil and Groundwater Operable Unit (S&G-OU1)
02	Tank Farms OU (TF-OU2)
03	Lockheed Upland OU (LU-OU3)
04, 05, 06	No longer considered as operable units
07	Lockheed Shipyard Sediments OU (LSS-OU7)
08	West Waterway OU (WW-OU8)
09	Todd Shipyards Sediments OU (TSS-OU9)
10	East Waterway OU (EW-OU10)

Post Remedial Activities are occurring at the different operable units concurrently. In addition, there are several PRPs that have interests in particular land parcels on the island and are involved in more than one OU.

2.2 CHRONOLOGY

The following is a listing of significant events that occurred at the Site. The chronology for each OU is listed separately since each has its own specific dates.

Table 2-1. Chronology of Site Events – Harbor Island (Initial Site-Wide Actions)

Event	Date
Initial discovery of site under CERCLA	01/01/80
Preliminary Assessment, Site Investigation	03/01/80
NPL Listing, Site-wide	09/08/83

Table 2-2. Chronology of Site Events – S&G-OU1

Event	Date
Remedial Investigation/Feasibility Study (RI/FS) start for Island Wide Soil and Groundwater OU (S&G-OU1)	09/07/88
Record of Decision (ROD) for S&G-OU1	09/30/93
Consent Decree with rest of PRPs, for RD/RA, S&G-OU1	08/06/96
Explanation of Significant Differences No. 1	7/26/94
Amended ROD Issued	01/25/96
Explanation of Significant Differences No. 2	09/26/01
"Hot Spot" removals addressed	1996-2002
T18 Expansion and Capping Completed	04/02

Table 2-3. Chronology of Site Events – TF-OU2 (Ecology Lead)

Event	Date
RI/FS start for Tank Farms	1994
Completion of RI/FS	1997
Restrictive Covenant Equilon	10/98
CAP[a] issued for Equilon	11/98
Consent Decree, Equilon	04/99
CAP[a] issued for GATX	12/99
CAP[a] issued for ARCO	01/00
Engineering Design Report, Equilon	03/00
Consent Decree, GATX	04/00
Consent Decree, ARCO	04/00
Restrictive Covenant, ARCO	05/00
Restrictive Covenant, GATX	06/00
Engineering Design Report, ARCO	08/00
Soils Excavation Completion Report, ARCO	03/01
Engineering Design Report, Kinder Morgan (GATX)	06/01
Soils Excavation Completion Report - Shoreline Manifold and Main Terminal Areas, Equilon	02/02
Soils Excavation and Groundwater Remedy Construction Completion Report, Kinder Morgan (former GATX)	11/02
Groundwater Remedy Construction Completion Report, BP(ARCO)	09/03
Soils Excavation Completion Report – Main Tank Farm, Shell (Equilon)	11/04

[a] Cleanup Action Plan (CAP) is the Ecology equivalent to an EPA ROD.

Notes: GATX facility is now owned and operated by Kinder Morgan Energy Partners.
ARCO facility is now owned and operated by BP West Coast Products.
Equilon facility is now owned and operated by Shell Oil Products US.

Table 2-4. Chronology of Site Events – LU-OU3

Event	Date
Administrative Order, RI/FS, with Lockheed, LU-OU3	09/14/90
RI/FS Completion	6/28/94
ROD	6/28/94
Remedial Design/Remedial Action (RD/RA) start at Lockheed Property, LU-OU3	09/30/94
Consent Decree for Cleanup of Lockheed Upland Property, LU-OU3	02/27/95
Completion of Construction for Lockheed Upland Property, LU-OU3	12/27/95
RA Completion	12/27/95
Partial Delisting for Lockheed Upland Property, LU-OU3	11/07/96
Partial Deletion, Lockheed Upland	11/07/96

Table 2-5. Chronology of Site Events – LSS-OU7

Event	Date
Washington Department of Ecology performed preliminary investigation of the island to determine nature and extent of contamination.	1985
EPA completed an initial Remedial Investigation (RI) of marine sediments around Harbor Island.	1994
Potentially responsible parties completed Supplemental Remedial Investigation to further characterize the extent of contamination in the Harbor Island sediments.	1995
EPA issued a Record of Decision (ROD) selecting the remedy for the Shipyard Sediments Operable Unit (OU) and subdivides the Shipyard Sediments Operable Unit into two separate OUs, Todd Shipyards Sediments Operable Unit and Lockheed Shipyard Sediments Operable Unit.	1996
EPA issued an Administrative Order on Consent for Remedial Design (RD)	7/16/1997
EPA issued an Explanation of Significant Differences.	2/22/2002
EPA issued an Explanation of Significant Differences.	3/31/2003
Consent Decree finalizing settlement for responsible party performance of remedy entered by Federal Court.	7/23/2003
EPA approved Potentially Responsible Party (PRP) Remedial Design for demolition.	7/2/2003
Start of Phase 1 remedial action – pier demolition.	7/7/2003
EPA approved PRP Remedial Design for dredging and capping.	10/25/2003
Completion of Phase 1 construction season.	3/10/2004
EPA approved PRP Remedial Design for Phase 2 construction season.	10/18/2004
Start of Phase 2 remedial action – dredging and capping of contaminated sediments.	10/22/04
Completion of Phase 2 remedial action – dredging and capping of contaminated sediments.	2/4/2005
Final Construction Inspection.	[a]
Final Construction Completion Report.	[a]
Final Operations, Maintenance, and Monitoring Plan (OMMP).	[a]
Final Source Control Report	[a]

[a] Date under EPA review.

Table 2-6. Chronology of Site Events – WW-OU8

Event	Date
Preliminary Investigation	1984
Completed Storm Drain Cleanup	1989
Initial Remedial Investigation (RI) Sediment Sampling	1990
Completed Sediment RI	1993
Completed Sediment Feasibility Study (FS)	1994
Conducted Supplementary RI Sediment Sampling	1995
Initiate Tributyltin Studies	1996
Human Health Risk Assessment for Sediments in West Waterway OU	1998
Completed Tributyltin Studies	1998
Proposed Plan for West Waterway OU	1998
Updated Risk Assessment Information for West Waterway OU	2002
No Action ROD for West Waterway OU	9/11/03

Table 2-7. Chronology of Site Events – TSS-OU9

Event	Date
EPA completed an initial Remedial Investigation of marine sediments around Harbor Island.	1994
PRPs completed Supplemental Remedial Investigation to further characterize the extent of contamination in the Harbor Island sediments.	1995
EPA issued a Record of Decision selecting the remedy for the Shipyard Sediments Operable Unit and subdivides the Shipyard Sediments Operable Unit into two separate OUs, TSS-OU9 and LSS-OU7.	1996
EPA issued an Explanation of Significant Differences.	12/27/1999
EPA issued Administrative Order on Consent (AOC) for Remedial Design.	4/25/2000
EPA issued an Explanation of Significant Differences.	4/7/2003
Consent Decree finalizing settlement for responsible party performance of remedy entered by Federal Court.	7/21/2003
EPA approved PRP Remedial Design.	5/25/2004
Start of on-site construction for building/structures demolition (First phase of Todd Shipyards Sediments Operating Unit [TSS-OU9] Remedial Action).	7/6/04
Start of contaminated sediment dredging and capping for 2004/5 season.	8/15/04

Table 2-8. Chronology of Site Events – EW-OU10

Event	Date
Initial RI Sediment Sampling	1990
Completed Sediment RI	1993
Completed Sediment FS	1994
Conducted Supplementary RI 1 Sediment Sampling	1995
Conducted Supplementary RI 2 Sediment Sampling	1996
Human Health Risk Assessment for Sediments in West Waterway OU (this included seafood tissue samples from East Waterway)	1998
Completed Dredge Characterization Study, Terminals 18, 25, 30	1998
Completed Stage 1 Maintenance Dredging	2000
Completed Post Dredge Monitoring of Stage 1 Area	2000
Conducted Supplementary RI Stage 3 Sediment Sampling	2001
Identified 12 Areas for Early Removal Action	2002
Started Phase 1 Removal Action of Contaminated Sediments	2004
Complete Phase 1 Removal Action of Contaminated Sediments	2005
Settlement Agreement for Final Supplemental Remedial Investigation and Feasibility Study Signed	2006
Sediment and Tissue Sampling for SR/FS completed	2009

3. BACKGROUND

3.1 PHYSICAL CHARACTERISTICS

Harbor Island is among the largest man-made islands in the United States and is located approximately one mile southwest of downtown Seattle in King County, Washington. The island lies at the mouth of the Duwamish River on the southern edge of Elliott Bay, in Puget Sound. The 420-acre island was created during the dredging of the lower Duwamish River between 1903 and 1905. The dredge spoil was deposited across the island. Subsequent bulkhead construction and filling has brought the island into its current configuration (Figures 2-1 and 2-2). The former Duwamish River channel and surrounding floodplains were filled and graded to form the present-day topography. Dredging in 1903 to 1905 created the East and West Waterways, and dredged material from the river was used to create Harbor Island. The present urban and developed shoreline is primarily composed of piers, riprap bank lines, and constructed bulkheads for industrial and commercial use.

The island upland is divided into three operable units; Soil and Groundwater OU (S&G-OU1), Tank Farms OU (TF-OU2), and Lockheed Upland OU (LU-OU3). The island is currently over 90 percent covered with impervious surfaces. The island is within the Seattle City Limits. The closest residential properties to Harbor Island are off the island approximately one-half mile away.

The Lockheed Shipyard Sediment OU (LSS-OU7) consists of contaminated nearshore sediments within and adjacent to the former Lockheed Shipyard on Harbor Island out to the edge of the steep slope of the West Waterway, which occurs at approximately the minus 36 (-36) foot mean lower low water (MLLW) contour (Figure 2-2). The Todd Shipyards Sediments Operable Unit (TSS-OU9) consists of contaminated nearshore sediments within and adjacent to the Todd Shipyards on Harbor Island (Figure 2-2). Todd Shipyards is located at the northwest corner of Harbor Island and faces Elliott Bay to the north and the West Waterway of the Duwamish River to the west.

The West Waterway OU (WW-OU8) includes approximately 70 acres of estuarine sediments located in the West Waterway on the western side of Harbor Island (Figure 2-2). The West Waterway is a dredged navigable channel used extensively for industrial and Port purposes. The waterway consists primarily of subtidal sediments, which remain underwater even at low tides. The shoreline of the West Waterway is predominantly pilings, bulkhead, and riprap. Areas of intertidal sediments along the shorelines adjacent to the West Waterway OU are generally nonexistent. No shoreline public access areas exist in the West Waterway OU.

The East Waterway Operable Unit (EW-OU10) consists of the East Waterway (EWW) adjacent to the east side of Harbor Island and its associated contamination. The bed of the EWW is owned by the State of Washington and managed by the Department of Natural Resources. The EWW is channelized, has a south-to-north orientation, and is approximately 5,800 feet long and 800 feet wide. The southern 1,500-foot section of the EWW varies in width from 225 feet to approximately 130 feet near the West Seattle Bridge. The depth of the EWW ranges from 29 to 51 feet MLLW. Depths diminish to 7.2 feet MLLW at the southern end, in the vicinity of the West Seattle Bridge.

3.2 LAND AND RESOURCE USE

The island was primarily used for commercial and industrial activities including ocean and rail transport operations, bulk fuel storage and transfer, secondary lead smelting, lead fabrication, shipbuilding, and metal plating. Warehouses, laboratories, and offices also existed historically on the island. The land use on the island is changing from a variety of smaller businesses to large operations: Port of Seattle shipping container handling and storage, bulk fuel storage, and shipbuilding and repair. Marine activities occur around the entire island, and dredging has allowed deep draft (40-foot) vessels to berth along piers on the eastern side of the site. The groundwater has never been used as a domestic water source.

Todd Shipyard, the last remaining shipyard, initiated shipbuilding activities on the island in 1916. Todd Shipyards is currently a ship repair, construction, and conversion facility that services approximately 275 vessels a year including: Navy vessels, Coast Guard vessels, passenger ferries, barges, fishing vessels, cruise ships, tank vessels, and tug boats. The shipyard operates three dry docks at Piers 4, 5, and 6 for vessel repair and maintenance. A west sloping building berth is located on the West Waterway of the Duwamish River at Piers 1A and 1 for construction and launching of new vessels. Moorage berths are located along Piers 1, 2, 3, 4, 5, and 6. The existing facilities at Todd Shipyards include bulkheads, riprap protection of buttress fill slopes, pile-supported piers, floating dry docks, a pile-supported building berth, a pile-supported side launching way, and miscellaneous access ramps.

The Tank Farms OU (TF-OU2) area has been utilized for petroleum bulk storage and transfer operations since the 1940s. There are three adjacent tank-farm facilities, separately owned and operated currently by BP West Coast Products (BP, Kinder Morgan Liquid Terminals (KM), and Shell Oil Products (Shell). The tank farms are a terminus of a major northwest fuel pipeline and include 70 large, vertical aboveground tanks and numerous smaller ones that store a variety of petroleum products. Total storage capacity is nearly 100 million gallons. The tank areas are unpaved and enclosed within concrete dykes. Other infrastructure within the facilities include: extensive distribution pipelines (above and belowground), pumping and manifold stations, fuel-transfer terminals for ships, railroad cars, and tanker trucks; and buildings used for storage, offices, and other purposes.

The Harbor Island waterways are located within the boundaries of the federally-adjudicated Usual and Accustomed Fishing Area for the Muckleshoot and Suquamish Indian Tribes.

3.3 HISTORY OF CONTAMINATION

The Site has been investigated on numerous occasions beginning in 1980. Based on these studies, Harbor Island was listed on the National Priorities List (NPL) on September 8, 1983, due to elevated concentrations of lead in soil associated with the former lead smelter operations, as well as elevated concentrations of other inorganic and organic substances. The soil on Harbor Island had lead, arsenic, and TPH concentrations well above acceptable human health risk levels which were identified and quantified in the remedial investigation and feasibility studies that have been completed. In addition, spills and leaks of product at the petroleum tank farms have created several areas of localized soil contamination in both TF-OU2 and in S&G-OU1. Active product extraction is occurring both in TF-OU2 and as part of the Todd Shipyards in the S&G-OU1.

General sources of potential contamination to the sediments surrounding Harbor Island were identified as direct discharge of waste, spills, historical disposal practices, atmospheric deposition, groundwater seepage, storm drains, combined sewer overflow systems, and other nonpoint discharges. Sediment contamination of the estuarine environment surrounding Harbor Island may also have resulted from upstream sources.

Shipbuilding and ship maintenance activities at Lockheed Shipyard and Todd Shipyards have resulted in the direct disposal of waste into sediments of the West Waterway and Elliott Bay adjacent to the shipyards. Much of the waste is believed to have originated from sandblasting, which is a process used to remove paint and paint preparations containing copper, lead, mercury, and zinc. Hazardous substances released from both shipyards include: arsenic, copper, lead, mercury, tributyltin (TBT) and zinc, which were additives to marine paints used on ships. Other hazardous substances potentially associated with shipyard activities include polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). Other sources of contamination at the Lockheed and Todd Shipyards which may have contaminated sediments include: public and private storm drains, non-point surface runoff from contaminated soil, direct waste disposal, floating petroleum product on groundwater and contaminated groundwater. Contaminants in sediments include PCBs, PAHs, TBT, arsenic, copper, lead, mercury, and zinc.

To summarize, the major contaminants found at Harbor Island that have been released to the different media in the environment include:

Soil	Sediments	Groundwater
• Lead • Arsenic • PCBs • TPH (Total Petroleum Hydrocarbon) • Trichloroethylene	• PCBs • PAHs • Arsenic • Copper • Lead • Mercury • TBT (Tributyltin) • Zinc	• PAH • PCBs • Copper • Trichloroethylene • Tetrachloroethylene • TPH (TPHG, TPHD, TPHO, BTEX, CPAHs) • Arsenic • Lead

3.4 INITIAL RESPONSE

An initial EPA inspection in 1982 of the lead smelter facility formerly located on Harbor Island identified lead-contaminated soil, which resulted in the listing of the entire island on the National Priorities List (NPL) in 1983, including the sediments in the adjacent waterways. The remedial investigation (RI) goal was to examine the nature and extent of the soil and groundwater contamination and the sediments lying just off-shore. In 1988, the Remedial Investigation began for the upland soil and groundwater part of the site (S&G-OU1). By 1993, the completed Feasibility Study (FS) had identified the type and extent of the soil and groundwater contamination and proposed removal and containment actions.

Significant remedial actions began within TF-OU2 during the early 1990s. Interim remedial systems were installed by facility owners at the time in the two shoreline areas to control release of petroleum to surface water. In 1991, a Memorandum of Agreement between Ecology and EPA established Ecology as the lead agency to oversee and complete cleanup of the TF-OU2. The island-wide RI conducted by the EPA in 1992 included the TF-OU2. Subsequent RIs were conducted under oversight by Ecology for each of the three tank-farm facilities. The RI work identified widespread areas of shallow soil that exceeded screening levels for arsenic and lead. Many localized TPH "hot spots" of various extents exceeding TPH screening levels for soil were identified in subsurface soil throughout TF-OU2. There were areas of some free product/sheen on groundwater, and broader areas where dissolved petroleum constituents (TPH, BTEX) exceeded screening levels. There were also minor detections of cPAHs and lead in the groundwater. A Feasibility Study (FS) was subsequently done for each tank-farm facility to determine appropriate cleanup actions.

The first investigation of marine sediments around Harbor Island was completed by EPA in 1988 as part of the Elliott Bay Action Program (EBAP). The nature and extent of contamination in Harbor Island sediments was characterized in an RI Report issued by EPA in September 1994. A Supplemental RI, conducted by a group of PRPs in 1996, further characterized the chemical contamination in Harbor Island sediments and reported results of biological effects tests conducted on sediments in the West Waterway of Harbor Island, which included a few locations in the Todd Shipyard, and which became the Todd Shipyards Sediment Operable Unit (TSS-OU9).

The shipyard operable units were established because the sediments were identified as distinct from other contaminated sediments at Harbor Island. They are predominately contaminated with hazardous substances and shipyard wastes (primarily sandblast grit) released by shipbuilding and maintenance operations from Todd and Lockheed.

No removal or early actions were completed for the marine sediments at the Harbor Island Site. The initial RI/FS for sediments associated with this Harbor Island OU was performed as fund-lead, with subsequent investigations performed by Respondents pursuant to Administrative Orders on Consent with U.S. EPA.

Numerous sediment investigations were conducted in the West Waterway from 1985 through 2000 to identify potential adverse ecological effects and human health risks associated with marine sediments. Studies included: surface sediment chemistry, sediment toxicity bioassays, tributyltin bulk sediment and porewater analyses, tributyltin laboratory bioaccumulation tests, and crab/sole/perch tissue collection and analysis for the human health risk assessment.

The highest concentrations of chemicals in sediments in the West Waterway were associated with the Shipyard Sediments OU and resulted in a separate ROD for the Lockheed and Todd Shipyard Sediment Operable Units being signed on November 20, 1996. This ROD divided the Sediment OUs into separate OUs for Lockheed and Todd and describes the basis for taking action with the shipyard sediment due to adverse ecological effects. (See Section 4.4 for a discussion on the subdivision of the Shipyard Sediments OU into two separate OUs: the Todd Shipyards Sediments OU and the Lockheed Shipyard Sediments OU.) For the remaining sediments, the results of these studies did not indicate a basis for taking remedial action with the West Waterway, and a No-Action ROD was signed.

In 1996, the Port of Seattle, under EPA oversight, sampled the East Waterway (EW-OU10) as part of a dredging characterization in order to complete dredging as a navigational improvement in East Waterway along Terminals 18, 30, and 25. A summary of dredging activities can be seen in Figure 3-1 (located at the end of this document). This characterization revealed areas of the waterway that contained moderate to high levels of contamination and required moderate to high levels of dredging for navigation. In 1999, the U.S. Army Corps of Engineers (USACE) performed maintenance dredging along T-18 (Stage 1 Dredging). As required by the EPA, post dredge monitoring was completed in 2000, which indicated that contamination at depth in the area was higher than expected, although below the Washington State Sediment Management Standards (SMS) chemical cleanup screening level. Based on these findings, EPA decided that additional environmental dredging should be performed under EPA oversight. In 2005, the Port of Seattle, through an agreed order with the EPA, removed 260,000 cubic yards of material. Of that total, 60,000 cubic yards were suitable for open water disposal. A 9-inch variable sand layer was placed over the post dredge surface in order to prevent exposure to benthic organisms from remaining contamination that existed above State Sediment Management Standards. Current recontamination monitoring indicates increasing chemical concentrations above State standards. This area will be part of the cleanup decision expected in 2013.

3.5 SUMMARY OF BASIS FOR TAKING ACTION

An assessment of the human health risks at Harbor Island identified people who may incidentally ingest soil or have dermal contact with soil as the population most at risk of adverse health effects. Inhalation was not determined as a significant pathway of exposure to contaminants on the upland of Harbor Island.

Exposure to contaminants in groundwater was not evaluated because there is no current or foreseeable use of groundwater for drinking water purposes. The entire island is serviced by the City of Seattle water system, and the majority of groundwater beneath the island is naturally brackish and not suitable for drinking. EPA and Ecology determined that national ambient water quality standards for surface water would apply as applicable and relevant and appropriate requirements (ARARs) at the shoreline. For Harbor Island, the surface water ARARs are the marine chronic criteria in the "Water Quality Standards for Surface Waters of the State of Washington" and the human health criteria for consumption of marine organisms in "Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; State's Compliance Final Rule."

A habitat evaluation for the upland determined that Harbor Island is unable to sustain a wildlife population or support a functioning wildlife habitat due to the widespread industrial development. Therefore, an ecological risk assessment was not completed for the upland OUs.

The results of these studies did not indicate a basis for taking remedial action with the West Waterway.

4. REMEDIAL ACTIONS – REMEDY SELECTION, REMEDY IMPLEMENTATION, SYSTEM OPERATIONS/OPERATION AND MAINTENANCE (O&M)

4.1 SOIL AND GROUNDWATER OPERABLE UNIT (S&G-OU1)

4.1.1 Remedy Selection

The Record of Decision (ROD) for the S&G-OU1 was signed on September 30, 1993, and amended on January 25, 1996. The remedial action objectives were to:

1. Protect human health from exposure to contaminants in surface soil which pose a combined risk of greater than $1x10^{-5}$.
2. Protect human health from infrequent exposure to contaminants in the subsurface which pose a risk greater than $1x10^{-5}$ for each contaminant. Prevent release of contaminants into the groundwater where they can be transported to the shoreline, where marine organisms could be exposed.
3. Prevent migration of contaminants to the shoreline where marine organisms could be exposed. Protect human health from consuming contaminated marine organisms which pose a risk greater than $1x10^{-6}$.

The components of the selected remedial action identified in the ROD are listed below.

1. Excavate hot spot soils and treat or dispose off-site. Hot spots are defined as soils with TPH concentrations greater than 10,000 mg/kg; PCBs greater than 50 mg/kg; and mixed carcinogens with a total risk greater than $1x10^{-4}$. TPH hot spot soil, which was determined to be non-dangerous waste, was disposed of at Roosevelt Regional Landfill in Klickitat County, Washington. PCB and hot spot soil with greater than 10^{-4} risk would be sent off-site for treatment (incineration) or disposed in a hazardous waste landfill.
2. Cap exposed contaminated soil exceeding cleanup goals. The cap would consist of low permeability material such as asphalt or concrete. New pavement is required to have a minimum thickness of 3 inches and a maximum permeability of 1×10^{-5} cm/s. Existing asphalt and concrete surfaces that are damaged and located in areas where soils exceed cleanup levels were to be replaced or repaired to prevent infiltration of rainwater.
3. Invoke institutional controls which would require long-term maintenance of new and existing caps, warn future property owners of remaining contamination under capped areas on their properties, and specify procedures for handling and disposal of excavated contaminated soil from beneath capped areas if future excavation is necessary.
4. Remove and treat floating petroleum product and associated contaminated groundwater at Todd Shipyard.
5. Implement groundwater monitoring for 30 years, with review of groundwater trends every 5 years to assess the effectiveness of the selected remedy.

4.1.2 Remedy Implementation

A Consent Decree for the S&G-OU1 was signed on August 6, 1996, and lists the Settling Defendants responsible for implementing the remedies described in the ROD. The following remedial actions have been completed.

Hot Spot Soils Removal and Capping. All of the Hot Spot Soils that had COCs above on-site containment concentrations have been removed and disposed of off-site or properly treated. In 2003, the Port of Seattle finished expanding their cargo container facility (T18) by acquiring approximately 90 acres within the interior of Harbor Island. Contaminated soils exceeding cleanup criteria on the expansion properties were capped according to the requirements of the Consent Decree.

Institutional Controls. To warn future property owners of the remaining contamination, the Consent Decree required that the Settling Defendants record a certified copy of the Consent Decree in the appropriate King County office. Thereafter, each deed, title, or other instrument conveying an interest in a property included in the S&G-OU1 was required to contain a recorded notice that the property is subjected to the Consent Decree (and any lien retained by the United States) and to reference the recorded location of the Consent Decree and any restrictions applicable to the property. EPA has requested copies of the recorded documents as part of the Institutional Control Study for this Five-Year Review (see Section 6.2.2). EPA has received and is reviewing the information, and further discussion is needed with the PRPs regarding the implementation and finalization of ICs. Long-term maintenance of the cap areas were to be verified through annual cap inspections.

Todd Shipyards LNAPL Recovery. Todd Shipyards has been operating a light non-aqueous phase liquid (LNAPL) recovery system within the facility boundaries since 1998. Several system modifications have been completed since start-up including a vacuum-enhancement system installed in 2001 and installation of additional recovery wells in 2005 and 2009.

Long-Term Groundwater Monitoring. The ROD required semi-annual long-term groundwater monitoring at selected wells across Harbor Island for a period of 30 years. An EPA-approved groundwater monitoring plan was completed in 2009 (ENSR 2008c).

4.1.3 System Operation/Operation and Maintenance

Institutional Controls. As part of Institutional Controls (ICs), property owners are required to perform annual cap inspections and maintenance to ensure protection of site workers from dermal contact and reduce infiltration from rainwater. Figure 4-1 (located at the end of this document) shows the cap areas within the S&G-OU1. The Cap Inspection and Maintenance Plan for the Design Set 1B properties, which include Union Pacific Railroad Company Parcel A, The Dutchman LLC., King County/Fischer Mills, and Paul M. and Dianne Defaccio, is included in the Capping Remedial Action Implementation Report (RETEC 1998). The Cap Inspection and Maintenance Plan for the Design Set 2 property, which consists of the Port of Seattle T18, is included in the Design Set No. 2 Capping Implementation Report (RETEC 2006b).

The surface conditions and conditions along structures are the two main components of the inspection. The surface is inspected for cracking, damage, settlement, and standing water. It is assumed that if the top surface of the cap is in acceptable condition, then the underlying layers are also acceptable. Criteria for maintenance are:

- Less than 3 Inches of Settlement: Patch the area using standard asphalt to restore the area to the original grade.
- Greater than 3 Inches of Settlement: Remove/replace the asphalt and base course, replace subballast and/or ballast, or replace topsoil.

The Port of Seattle and Fisher Mills/King County have submitted cap inspection reports. Additional discussion of cap inspection and maintenance is presented in Section 6.2.2.

Todd Shipyards LNAPL Recovery. The LNAPL recovery system at Todd Shipyards uses specific-gravity skimmers that are connected to a pneumatically-operated skimmer pump located in each recovery well. The pump withdraws LNAPL from the skimmer inlet and pumps it out to an aboveground storage tank. To induce LNAPL flow, groundwater is extracted separately using electric submersible pumps. The drawdown is set at approximately 1 foot below the typical seasonal low groundwater elevation and is controlled by a transducer set in each well. The extracted groundwater is routed to a central shed where it is treated with carbon prior to discharge to the sanitary sewer.

The original LNAPL system consisted of four recovery wells and a belt skimmer set inside a monitoring well at one location with thick Bunker C type NAPL. Several system improvements have been implemented since operation began in 1998. In April 2001, a vacuum-enhancement system was installed to increase the flow of groundwater and non-aqueous phase liquid (NAPL) to the well. The unsaturated soils surrounding each recovery well are put under negative pressure maintained by a blower located in a central shed. The air discharged from the blower contains volatile organic compounds (VOCs) that are treated in a catalytic oxidizer prior to being discharged to the atmosphere. In 2004, the method for extracting groundwater switched from a centrally located jet pump to an independently controlled electric submersible pump to eliminate iron fouling problems. The groundwater treatment system was also switched from an air stripper to liquid phase carbon drums to eliminate iron fouling on the stripper trays.

The following additional changes to LNAPL recovery system network have been made since start-up:

- In 2005, the existing system was adjusted by discontinuing pumping at FW-2 (LNAPL recovery continued by skimming only) and stopping the recovery of viscous product at FW-10. Three new recovery wells were installed, FW-15, FW-16, and FW-17, along with a second recovery system shed for two of those wells.
- In 2006, FW-2 and FW-5 ceased recovering and the wells were taken off-line.
- In early 2008, FW-15 and FW-17 ceased recovering LNAPL.

Performance monitoring for the LNAPL recovery system is described in the Design Set No. 1A, LNAPL Remediation, Report (Landau 1998) and includes 1) determination of individual well LNAPL recovery rates and cumulative recovery volume, 2) determination of total LNAPL recovery rates and cumulative recovery volume, 3) measuring product thicknesses in the recovery wells and monitoring wells, and 4) determination of the hydraulic capture zone of the recovery system. Recovery rates are calculated on a monthly basis, and product thickness is measured on a quarterly basis. Progress reports are submitted to EPA on a quarterly basis.

Long-Term Groundwater Monitoring. Long-term monitoring is required to determine if contaminants are migrating to the shoreline where marine organisms could be exposed and confirm the performance of the soil remedial actions. The monitoring network consists of three components: 1) compliance wells located near the shoreline, 2) early warning wells located inland of the compliance wells, and 3) S&G-OU1 boundary wells where the S&G-OU1 adjoins other OUs rather than surface water. Long-term groundwater monitoring has been performed since 2005. Reports documenting the monitoring events are submitted annually and can be reviewed at the EPA Region 10 Superfund Records Center (RETEC 2006c, ENSR Corporation 2008d, AECOM 2009c).

4.2 TANK FARMS OPERABLE UNIT (TF-OU2)

4.2.1 Remedy Selection

Information for the Tank Farm Operable Unit (TF-OU2) has been provided by the Washington Department of Ecology who is the lead agency overseeing cleanup of this OU.

Consent Decrees and associated Cleanup Action Plans (CAPs), which are Washington State Department of Ecology equivalent of EPA RODs, were established with facility owners during 1999 and 2000. The facility boundaries are shown on Figure 4-2 (located at the end of this document) and include:

- Shell Oil Products Seattle Terminal, Harbor Island (formerly Equilon Enterprises). Comprised of the Shell Main Terminal and Tank Farm, Shell's North Tank Farm area (located 300 feet north of Shell's Main Tank Farm) and Shell's Shoreline Manifold area (located 1,200 feet north of Shell's Main Tank Farm).
- BP West Coast Products (formerly ARCO Bulk Fuel Storage Facility Harbor Island). Comprised of Plant 1 and Plant 2.
- Kinder Morgan (KM) Liquids Terminal, Harbor Island (formerly GATX Terminals). Comprised of Yards A through E.

Indicator Hazardous Substances identified within the Tank Farms OU included:

Soil	Groundwater
• TPH (shallow and subsurface soil) • Arsenic (shallow soil) • Lead (shallow soil)	• Free product/sheen • TPH Gasoline, Diesel, and Oil range • Benzene, Toluene, Ethylbenzene, Xylenes Carcinogenic PAHs Lead

Cleanup levels for these substances were established in the CAPs for each facility within the TF-OU2 and were mostly identical to cleanup levels established in the EPA RODs for S&G-OU1 and LU-OU3. The cleanup levels for soil were considered protective of industrial worker exposure. The cleanup levels in groundwater were considered protective of surface water (aquatic organisms in Elliot Bay).

The objectives of the remedial actions were to remove all accessible contaminated soil and to achieve groundwater cleanup levels at the shoreline areas and inland property boundaries.

The selected remedial components included:

1. Excavate and remove shallow surface soil (6 inches) in areas exceeding 1,000 ppm lead and/or 32 ppm arsenic.
2. Excavate and remove accessible surface and subsurface soil in areas exceeding 10,000 ppm total TPH at identified areas adjacent to the shoreline and inland, where a large release occurred in 1996. Excavate and remove soil exceeding 20,000 ppm total TPH throughout all other inland areas. An overriding consideration regarding excavation of contaminated soils was to avoid any risk to the petroleum storage tanks and pipelines.

3. Construct and/or operate in situ remedial systems to treat contaminated soil and groundwater. The systems include free product/groundwater recovery, air sparging, and soil vapor extraction (SVE) components. Supplemental active free product recovery by passive methods in specific wells as needed.
4. Utilize natural attenuation processes to reduce contaminant levels in soil and groundwater. This was an inherent part of the remedy for inaccessible contaminated soils left in place to avoid risk to infrastructure.
5. Perform long-term groundwater monitoring, examine wells for free product, measure groundwater elevations at wells, and construct seasonal groundwater flow maps. Analyze groundwater samples for contaminants of concern (TPH-G, TPH-D, TPH-O, BTEX, cPAHs, Arsenic, Lead). Also analyze for natural attenuation parameters (DO, ORP, Carbon Dioxide, Methane, Ferrous Iron, Nitrate, Sulfate, Alkalinity) to evaluate natural attenuation processes.
6. Institute Restrictive Covenants. The Restrictive Covenants identified the contamination that existed at each facility, provided for the continued industrial use of the property, prohibited groundwater taken from the property, provided for the safety and notification of site workers, prohibited activities that would release or cause exposure to contamination, provided for continuance of remedial actions given property transference, and provided for Ecology access.

4.2.2 Remedy Implementation

The following remedial actions have been completed at TF-OU2.

Removal of Lead-Arsenic Contaminated Surface Soil. Excavation of near-surface lead-arsenic contaminated soil in areas throughout the main Tank Farm at the Shell facility was completed December 2003 through February 2004. Approximately 2,929 tons of impacted soil were removed and disposed of at the Roosevelt Regional Landfill in Klickitat County, Washington. Soil cleanup standards for lead (1,000 ppm) and arsenic (32 ppm) were achieved throughout this area. A small area of lead-contaminated soil near an oil-water separator at the Shell facility was excavated during October 2001, and approximately 75 tons of impacted soil was removed. Due to structural constraints, some subsurface soil remains above the lead standard in this area and it was capped with 3 inches of low-permeability asphalt.

Excavation of near-surface lead-arsenic contaminated soil throughout large areas in B and C Yards at the KM facility was completed April through May 2002. Approximately 11,094 tons of impacted soil was removed and disposed of at the Waste Management Columbia Ridge Landfill and Recycling Facility in Arlington, Oregon. Soil cleanup standards for lead (1,000 ppm) and arsenic (32 ppm) were achieved throughout these areas.

No removal of lead/arsenic contaminated surface soil was required at the BP facility.

Removal of TPH Contaminated Surface and Subsurface Soil. All TPH "hot spots" identified in the original RI work and CAPs have been addressed. A description of the removals is presented below.

Numerous discrete areas of TPH-contaminated soil above established cleanup standards of either 10,000 ppm or 20,000 ppm were identified throughout all three tank farms. The 10,000-ppm standard applied to areas adjacent to surface water (Shoreline Manifold area at the Shell facility and Plant 1 at the BP facility) and in the area of a 1996 release (C Yard) at the KM facility. The 20,000-ppm standard applied to inland areas of the tank farms. Impacted soil above applicable standards was mostly removed in these areas and transported to

appropriate facilities off-site for treatment or disposal. Some subsurface soil above applicable standards remains in most of these areas because of the safety constraints imposed on excavating by existing structures (primarily the aboveground tanks). Three areas of TPH-impacted soil were excavated at the Shell facility. One area was completed near a former UST (20,000 ppm standard) during October 2001 (33 tons). Another area was partially completed in the Shoreline Manifold area (10,000 ppm standard) during November 2001 (111 tons). The third area was completed in the Main Tank Farm (20,000 ppm standard) during February 2004 (57 tons).

Seven areas of TPH-impacted soil were excavated at the KM facility during April and May 2002 (32,948 tons total). One area was in B Yard (20,000 ppm standard) and six areas were in C Yard (10,000 ppm standard). Applicable standards were achieved in four of these areas.

Six major areas of TPH-impacted soil were excavated at the BP facility during September and October 2000 (5,205 tons total). Two areas were in Plant 1 (10,000 ppm standard) and four areas were in Plant 2 (20,000 ppm standard). Oxygen-release compound was emplaced in one excavation at Plant 2 to enhance biodegradation.

Complete removal of an area of TPH-contaminated subsurface soil identified by the RI in the Shoreline Manifold area of the Shell facility had been precluded by a run of several large fuel pipelines in the area. During 2006, a new bulkhead was constructed and these pipelines were removed. Eleven borings were done throughout the previously identified area of remaining subsurface soil exceeding the 10,000 ppm total TPH cleanup standard in this shoreline area. The borings were done to determine current remaining TPH contaminant levels in the soil. Results indicated that total TPH contaminant levels had attenuated to below 10,000 ppm throughout 70 percent of the previously-identified area. The attenuation is probably attributable in part to the former remedial system that operated in this area, and also to natural attenuation over a 12-year period. Soil remaining above 10,000 ppm TPH (40 cubic yards) was removed during October 2009.

The RI work indicated levels of contamination in the subsurface soil in A Yard of the KM facility exceeding the 20,000 ppm total TPH standard applicable in this inland area. The CAP for the facility required further investigation and excavation of these areas to the extent technically practicable after free product in groundwater had been removed from this area. Over the years, free product has mostly disappeared in the area (to the extent of occasional minor sheens in some wells) through both active and passive product-removal remediation actions. During October 2009, seven borings were advanced to investigate the areas where high levels of TPH were previously indicated in subsurface soils. Results indicated that total TPH levels in soil had attenuated in these areas over a 12-year period to levels well below the 20,000 ppm cleanup standard (all values were below 5,000 ppm). No removal of subsurface soil will be required in this area given the results of the investigation.

Additional soil excavation was completed during upgrades to the Shell facility in 2007, when an array of aboveground fuel piping was removed near Tank 80000. Petroleum contaminated soil was observed in this previously inaccessible area. Nine borings were completed to investigate the extent of the contamination. The contamination was Bunker Oil apparently from a historical spill. Subsequent excavation removed 16 cubic yards of contaminated soil. Conformation samples indicated remaining soil was below the 20,000 ppm total TPH standard applicable in this area.

Construction and Operation of In-Situ Remedial Systems. A summary of the remediation systems that have operated or are currently operating at TF-OU2 is as follows:

- A free product recovery and vapor extraction system operated at the shoreline in the Shoreline Manifold area of the Shell facility prior to the Consent Decree until 2005 when product was no longer observed and hydrocarbon recovery through vapor extraction declined.
- A point-source free product recovery at the KM facility A and B Yards operated from October 2002 through 2004 when product was no longer observed.
- An air sparge system consisting of 16 sparge wells at the KM facility C Yard operated from October 2002 through August 2004 when groundwater cleanup standards had been achieved and maintained.
- An SVE/air sparge system at the KM facility A Yard has been operating since 2006. Additional discussion of this system is presented in Section 6.3.2.
- A free product recovery and vapor extraction system at the bulkhead area of BP Plant 1 has been operating since 1992. The system was expanded in 2003 as a requirement of the CAP to include greater capacity for free product/groundwater recovery and add vapor extraction and air sparging components and continues to operate at present. Additional discussion of this system is presented in Section 6.3.2.
- An SVE system at BP Plant 1 southern boundary has been operating since 2008. Additional discussion of this system is presented in Section 6.3.2.
- Minor passive free product recovery is occurring in three wells at the Shell facility and three wells at the KM facility.

Natural Attenuation. Select wells are analyzed for indicator parameters to evaluate natural attenuation processes. These included dissolved oxygen, ferrous iron, methane, sulfate, sulfide, carbon dioxide. Declining contaminant levels in some wells near remaining areas of subsurface TPH contamination provide evidence for natural attenuation in these areas.

Groundwater Monitoring. Numerous monitoring wells at the tank farms were in place prior to the Consent Decrees and additional wells were installed afterwards. Monitoring wells throughout the tank farms were regularly examined for free product and/or sampled for the contaminants of concern and natural attenuation parameters. The wells include approximately 30 at the Shell facility, 80 at the KM facility, and 20 at the BP facility. Wells are sampled quarterly and examined for free product as often as monthly. Wells designated for particular monitoring activities are specified in the Groundwater Compliance Monitoring Plan for each facility. Two compliance monitoring wells in the Shoreline Manifold area at the Shell facility and five compliance monitoring wells in Plant 1 at the BP facility are screened in groundwater at depths below the bottom of each bulkhead to monitor possible discharge of contaminants to surface water. Other monitoring wells are screened at the water table.

Institutional Controls. Institutional Controls were required in the form of Restrictive Covenants for each facility and were required to be written and recorded 10 days after the signing of each Consent Decree. The restrictive covenants for BP, KM, and Shell were filed with King County on August 15, 2000, August 30, 2000, and October 5, 2000, respectively.

4.2.3 System Operation/Operation and Maintenance

In-Situ Remedial Systems. Operation and maintenance of the current operational remedial systems include:

1. The remedial system at the shoreline-bulkhead in BP's Plant 1 facility. The current system expanded upon an earlier groundwater-product recovery interim system that operated since 1992. The current system became operational in early 2003, and was built with capabilities to recover product and groundwater and to perform soil vapor extraction and air sparging. The system was modified to operate in a pulsed mode to enhance performance, and also by adding two additional sparge wells for a time. During recent years, the system has experienced typical maintenance issues, including pump and compressor replacement and clogging of pipes by scale and biofouling. Ongoing clearing of piping by various means, including replacement, has been needed to maintain system operation and resulted in some downtime. Based upon SVE monitoring data indicating lack of further hydrocarbon recovery, the air-sparge and SVE components of the system were discontinued during 2008. The SVE and sparge capability of the system is being maintained in case of future need. The groundwater-product recovery component of the system continues to operate and provides hydraulic control of sheen and groundwater at the bulkhead.
2. The soil-vapor extraction system operating at the southern property boundary of BP's Plant 1 facility. The system has operated since October 2008 and performance monitoring data indicate gasoline-range hydrocarbons are being recovered. There have not been significant maintenance issues or down time with this new system.
3. The air-sparge/soil-vapor extraction system operating at the western property boundary of A Yard in the KM facility. The system has operated since December 2006 and performance monitoring data indicated petroleum hydrocarbons are being recovered. There have not been significant maintenance issues or downtime with this system.

The engineering design and operating components of each of these three remedial systems are documented in Construction Completion Reports and As-Built drawings. The acquisition of appropriate permits is documented. The Operations and Maintenance (O&M) procedures specific to each system are presented in O&M manuals prepared for each system. General system operations and maintenance activities along with the operating and performance parameters for each system are presented in required quarterly reports. Permitted discharge limits have not been significantly exceeded during the operations of these systems.

4.3 LOCKHEED UPLAND OPERABLE UNIT (LU-OU3)

During the site-wide RI/FS, two Lockheed Operable Units were established to allow the Lockheed Martin Corporation to proceed with the cleanup of their property on a different schedule from the rest of the Site (Figure 2-2). The Lockheed Upland, (LU-OU3), RI/FS was begun in 1990 and completed with a ROD signed in 1994. The remedial actions for this OU were completed on December 27, 1995. Part of the LU-OU3 was delisted on November 7, 1996 from the NPL, although site GW still remains on the NPL; however, so long as waste remains on-site under caps, Five Year Reviews continue to be required.

4.3.1 Remedy Selection

The ROD for the LU-OU3 was signed in June 1994. The objectives and selected remedial action are consistent with the S&G-OU1. The LU-OU3 remedial action objectives were to:

1. Protect human health from exposure to contaminants in surface soil which pose a combined risk of greater than $1x10^{-5}$.
2. Protect human health from infrequent exposure to contaminants in the subsurface which pose a risk greater than $1x10^{-5}$ for each contaminant. Prevent release of contaminants into the groundwater where they can be transported to the shoreline, where marine organisms could be exposed.
3. Prevent migration of contaminants to the shoreline where marine organisms could be exposed. Protect human health from consuming contaminated marine organisms which pose a risk greater than $1x10^{-6}$.

The components of the selected remedial actions outlined in the ROD are listed below.

1. Excavate and treat hot spot soils. Hot spots are defined as soils with total petroleum hydrocarbons (TPH) concentrations greater than 10,000 mg/kg. The TPH hot spot soil will be treated on-site by a thermal desorption system with an afterburner.
2. Contain exposed contaminated soil exceeding inorganic and organic cleanup goals. Containment was achieved with a 3-inch asphalt cap designed to reduce infiltration of rainwater and reduce contaminant migration into the environment. Existing asphalt and concrete surfaces that are damaged in areas exceeding cleanup goals were either replaced or repaired. Maintenance of the new and existing caps are required under a Consent Decree for the settling PRPs as long as they own the Lockheed facility.
3. Invoke ICs that will warn future property owners of the remaining contamination contained under capped areas on this property, require future owners and operators to maintain these caps, and specify procedures for handling and disposal of excavated contaminated soil from beneath capped areas if future excavation is necessary.
4. Monitor groundwater quality semi-annually for 30 years, or until it has been demonstrated that groundwater contaminants will not reach the shoreline in concentrations exceeding cleanup goals. The groundwater data will be reviewed every 5 years to assess the effectiveness of the selected remedy.

4.3.2 Remedy Implementation

A Consent Decree for LU-OU3 was signed on December 8, 1994, and the remedial actions were completed on December 27, 1995. The LU-OU3 was partially delisted on November 7, 1996. The Port of Seattle purchased a portion of the property in 1997, and sold the northeastern section to BP/ARCO, who developed it into a fueling station. The remaining Port of Seattle property is referred to as Terminal 10.

Hot Spot Soils Removal and Capping. All of the Hot Spot Soils have been removed and areas with organics and inorganics exceeding soil cleanup goals have been capped.

Institutional Controls. To warn future property owners of the remaining contamination, the Consent Decree required that a certified copy of the Consent Decree be recorded in the appropriate King County office. Thereafter, each deed, title, or other instrument conveying an interest in a property included in the LU-OU3 was required to contain a recorded notice that the property is subjected to the Consent Decree (and any lien retained by the United States) and to reference the recorded location of the Consent Decree and any restrictions applicable

to the property. EPA requested copies of the recorded documents as part of the Institutional Control Study (ICS) for this Five-Year Review (see Section 6.4.2) and is currently reviewing these documents. Certified copies of the consent decrees have not been recorded in the appropriate King County records office, and EPA is currently working with Lockheed Martin to completely fulfill the IC requirements set forth in the Consent Decree. Long-term maintenance of the cap areas were to be verified through annual cap inspections.

Long-Term Groundwater Monitoring. Semi-annual groundwater monitoring has been completed since 1996, and these results are discussed in Section 6.4.2.

4.3.3 System Operation/Operation and Maintenance

Institutional Controls. As part of the Institutional Controls, annual cap inspections and maintenance is required to ensure protection of site workers from dermal contact and reduce infiltration from rainwater. The integrity of the capped areas are inspected by examining them for cracks, breaches, and the presence of vegetation. These methods were presented in the Operations and Maintenance Plan included as Appendix B of the Remedial Action Work Plan. Due to the sale of the property, the Port of Seattle is responsible for the maintenance of the cap and submits reports annually.

Five cap areas currently require inspection at the LU-OU3 and are shown on Figure 4-3 (located at the end of this document). Soil removals during remediation and construction activities have modified some of the cap areas from the original construction in 1995. These include:

- Railway installation in 2000. The southernmost portions of Cap Areas 1 and 2 were removed. Groundwater monitoring wells LMW-4 and LMW-10 were decommissioned during construction.
- Fueling station constructed in 2002. All of Cap Area 5 and most of Cap Area 4 were completely repaved with 3 feet of asphalt.
- Lockheed Shipyard Sediment Operable Unit Remediation Program in 2003 and 2004. Cap Area 3 removed entirely and removed from the inspection program.

Groundwater Monitoring. The Lockheed uplands groundwater monitoring program consists of semi-annual sampling in April (wet season) and October (dry season). The network was designed to monitor specific contaminated areas. Each area has a monitoring well located near the source and a designated down-gradient well to determine if groundwater contaminants are migrating toward the waterway. Reports are submitted semi-annually.

4.4 LOCKHEED SHIPYARD SEDIMENT OPERABLE UNIT (LSS-OU7)

4.4.1 Remedy Selection

The ROD for the Lockheed and Todd Shipyards Sediment Operable Units was signed on November 30, 1996. This Record of Decision (ROD) also divided the Sediment OUs into separate OUs for Lockheed and Todd. Remedial Action Objectives (RAOs) were developed as a result of data collected during the Remedial Investigation (RI) to aid in the development and screening of remedial alternatives to be considered for the ROD. The RAO for the LSS-OU7 is to reduce concentrations of hazardous substances to levels that will have no adverse effect on marine organisms.

The major components of the remedy selected in the ROD include the following:

1. All sediment exceeding the chemical contaminant screening level of the State of Washington Sediment Management Standards (SMS) and all shipyard waste will be dredged and disposed of in an appropriate in-water or upland disposal facility.
2. All sediments exceeding the sediment quality standards (SQS) of the SMS will be capped with a minimum of 2 feet of clean sediment.
3. Specification of design criteria for acceptable habitat and to prevent future recontamination.
4. Institution of long-term monitoring and maintenance of the remedy.
5. The extent of dredging of contaminated sediments and waste under piers at the LSS-OU7 will be determined during remedial design based on cost, benefit, and technical feasibility.

Subsequent to the ROD, pre-remedial design studies for the LSS-OU7 better defined the nature and extent of contamination within the OU. The results of these studies indicated that certain elements of the ROD needed to be amended. The February 12, 2002, Explanation of Significant Differences (ESD) summarized the sediment characterization data, specified details regarding the dredge and cap remedy, and defined abrasive grit blast. The March 7, 2003, ESD established confirmation numbers to be used to distinguish contaminants characteristic of the West Waterway from contamination associated with the LSS-OU7; summarized the long-term monitoring, maintenance, and operational parameters; and identified the disposal option for contaminated sediments dredged from the LSS-OU7 as requiring upland disposal.

4.4.2 Remedy Implementation

In an Administrative Order on Consent (AOC) signed with EPA on July 16, 1997, Lockheed Martin agreed to perform the RD for implementing the remedy in conformance with the ROD as modified by the two ESDs. The RD was approved in parts. The RD for:

- Demolition of the wooden piers and piles was approved on July 2, 2003.
- First season dredging and capping was approved on October 25, 2003.
- Second season dredging, capping, and habitat enhancement was approved on May 25, 2004.

A Consent Decree (CD) between EPA and Lockheed was approved by the Court on July 23, 2003, to perform the remedial action (RA) and to pay past costs for cleaning up the site.

The RA was conducted in two phases. Phase 1 was completed on March 10, 2004, and Phase 2 was completed on February 4, 2005. The first phase of remedial construction efforts was focused on pier demolition and dredging of contaminated sediments. The second phase consisted of dredging, capping, and habitat enhancement.

The major components of RA were the following:

- Replace the existing deteriorated bulkhead wall so the upland soils will remain stable during and after remedial activities, including the following:
  - Pier and timber bulkhead removal.
  - Dredging adjacent to the bulkhead.
- Remove all existing pier structures including timber piling and portions of the existing shipway structures from aquatic areas of the site while maintaining the stability of the site.

- Dredge contaminated sediments from the channel and slope areas of the LSS-OU7 while maintaining stable slopes and critical habitat elevations.
- Design the dredge prisms and constructed slopes such that they will be constructible.
- In the Channel Area, remove the depth of sediment exceeding SQS criteria and construct a berm to support the Slope Area and maintain critical habitat elevation.
- Perform post-dredge sediment verification sampling and analysis to confirm achievement of SQS in the Channel Area.
- In the Slope Area, limit changes in the post-remediation of critical habitat elevations (i.e., between -4 to 8 feet Mean Lower Low Water [MLLW] from that of the existing condition while accommodating a 5-foot-thick cap.
- Construct an on-site mitigation area.
- Create intertidal habitat with clean soil in the vicinity of Pier 10 to mitigate habitat losses resulting from the partial filling of the South Shipway.
- Cap the Slope Area such that the cap will provide the following:
  - Chemical and physical isolation of the underlying contaminated sediments.
  - Protection of the chemical isolation portion of the cap from bioturbation and erosional forces.
  - A final cap surface that is compatible with marine organisms.
- Limited dredging and a sand cover boundary line along the offshore perimeter of the site (as a placeholder concept pending the results of further characterization in this area) to provide the following:
  - Partial removal, coverage, and enhanced natural recovery of contaminated off-site sediments located adjacent to the site.
  - A final substrate surface that is habitat compatible for marine organisms.

The LSS-OU7 was subdivided into Site Management Areas (SMAs) for the purposes of remedial design and action. The Channel (or open water) Area, identified as SMA 1, is the area running the length of the piers, outward from the pier face to the edge of the steep slope of the West Waterway at approximately -36 feet (MLLW). SMA 1 consists of unobstructed open water. The enclosed water SMA, SMA 2, is behind Pier 9. This is also an unobstructed area of open water that is bounded by the bank or bulkhead on one side and pier structures on two sides. SMAs 3, 5, and 7 designate sediment areas under the pier structure. Sediments under the shipways are designated as SMAs 4 and 6. Shipways are ramps that are used to move ships out of the water. These ramps contain decking like the pier structures and are held up by closely spaced pilings. SMAs 2 through 7 are collectively referred to as the Slope Area.

Table 4-1 summarizes the amount of material dredged in LSS-OU7 by material type. During this remedial action, 119,064 tons of contaminated sediments were dredged and transported to an approved upland facility for disposal.

Table 4-1. LSS-OU7, Total Tons of Contaminated Sediments and Debris Dredged

Dredging and Disposal Events	Weight in Tons	Notes
FIRST CONSTRUCTION SEASON (2003-2004)		
Dredge and Debris Disposal by Rail	85,096	864 Rail Cars
Soil and Dredge Disposal by Truck	1,118	
Creosote Treated Wood Disposal by Bins	10,660	442 Bins
Wood Salvage for Reuse	205	
Concrete Recycle	121	
Concrete w/Rebar Recycle	1,113	
Steel Recycle	36	
Subtotal:	**98,349**	
SECOND CONSTRUCTION SEASON (2004-2005)		
Dredge and Debris Disposal by Barge	21,107	15 Barges
Rock and Soil Disposal by Truck	586	
Creosote Treated Wood Disposal by Bins	21	1 Bin
Sample Disposal by Bin	1	1 Roll Off
Subtotal:	**21,715**	
TOTAL:	**119,064**	

Capping was implemented using approximately 100,000 cubic yards of capping material. Table 4-2 below shows the tonnage of each type of capping material placed on the slope area of the LSS-OU7.

Table 4-2. LSS-OU7, Tonnage of Capping Material Placed by Type

Capping Event	Weight in Tons	Notes
PHASE 1 CONSTRUCTION SEASON (2003-2004)		
Interim Cap	8,290	Covered entire OU.
Subtotal:	**8,290**	
PHASE 2 CONSTRUCTION SEASON – APPLIED BY MARINE EQUIPMENT (2004-2005)		
Toe Buttress Riprap	4,854	
Armor Riprap	13,501	
Sand Attenuation Cap Layer	21,479	
Filter Layer	5,951	
Rounded Filter/Armor Layer	1,451	1 Barge Load.
Fish Mix	8,667	
Subtotal:	**55,903**	
PHASE 2 CONSTRUCTION SEASON – APPLIED BY UPLAND EQUIPMENT (2004-2005)		
Armor Riprap	2,446	
Sand Attenuation Cap Layer	13,052	Includes Habitat Mix in some areas.
Rounded Filter/Armor Layer	17,018	
Fish Mix – Pit Run	3,001	
Subtotal:	**35,517**	
TOTAL:	**99,710**	

Eight sediment samples were collected from the post-dredge surface of the channel area (SMAs 1 through 7) to evaluate compliance with the design criteria. All analytical results were compared to the SQS chemical criteria to evaluate compliance. Out of 248 chemical analytical results, from eight samples, three samples exceeded the SQS for polychlorinated biphenyls (PCBs) only. Three other samples out of eight, or 30 analytical results out of 248, exceeded the SQS for a combination of chemicals of concern (COCs). Therefore, a total of 33 of 243 analytical results failed the SQS. Table 4-3 summarizes the nature and locations of exceedances and the corresponding remedial action.

Table 4-3. LSS-OU7, Nature and Locations of Exceedances and the Corresponding Remedial Action

Sampling Locations	SQS Compliance Criteria	Sampling Results	Remedial Decisions
SED-200	PCBs – 12 mg/kg	13 mg/kg	Pass
SED-201	PCBs – 130 µg/kg	146.5 µg/kg	ENR
SED-202		no exceedances	Pass
SED-203	As – 57 mg/kg LPAH – 370 mg/kg HPAH – 960 mg/kg PCB – 12 mg/kg	As – 73.4 mg/kg LPAH – 1620 mg/kg HPAH – 1937 mg/kg PCB – 21 mg/kg	ENR
SED-204	As – 57 mg/kg Cu – 370 mg/kg Zn – 960 mg/kg Hg – 0.41 mg/kg PCB – 12 mg/kg	As – 127 mg/kg Cu – 829 mg/kg Zn – 585 mg/kg Hg – 0.618 mg/kg PCB – 20 mg/kg	ENR
SED-205		no exceedances	Pass
SED-206	PCB – 12 mg/kg	PCB – 18 mg/kg	Pass
SED-207	As – 57 mg/kg Cu – 370 mg/kg Zn – 960 mg/kg Hg – 0.41 mg/kg LPAH – 370 mg/kg	As – 139 mg/kg Cu – 553 mg/kg Zn – 912 mg/kg Hg – 1.32 mg/kg LPAH – 1341 mg/kg	ENR

a ENR = Enhanced Natural Recovery

The remedial action for portions of the Channel Area, represented by samples SED-201, 203, 204, and 207, that failed to meet the cleanup numbers, was the addition of 6 inches of sand to the sediment surface, namely Enhanced Natural Recovery (ENR). Areas where there was an exceedance of PCBs only, no actions were taken because the exceedances were minor and were below the 90th percentile for PCBs present in the West Waterway based on bioassays.

Water quality monitoring during in-water remedial action was conducted according to the Water Quality Certification. Visual turbidity monitoring was performed during demolition of over-water structures, and intensive and routine water quality monitoring was performed during dredging and barge dewatering and filling/capping operations. Results of these monitoring events indicate that water quality remained within marine quality standards throughout the monitored events.

A Fish Coordination Plan was developed by Lockheed in consultation with EPA and affected Indian Tribes. There are two Treaty Indian Tribes that have reserved fishing rights in the lower Duwamish River including the area of the Lockheed sediment remediation. The

Muckleshoot and Suquamish cooperatively fish in these waters. Because in-water demolition, dredging, and capping activities would be occurring at the same time that Tribal fishing would be occurring, a Tribal Fishing Coordination Plan (Fish Coordination Plan) was developed jointly with the affected Tribes and Lockheed. The objectives of the Fish Coordination Plan were to:

1. Reduce the potential for conflicts between in-water construction operations and tribal fishing through effective communications and schedule planning.
2. Rapidly address any fishing equipment damaged as the result of construction operations within or adjacent to the site area.
3. Coordinate future construction activity (as practical) to reduce potential for further damage to fishing equipment.

According to the Fish Coordination Plan, ongoing communications between the Lockheed contractors and the Tribes successfully minimized conflicts between in-water construction and tribal fishing activities despite a high level of fishing activity and record catches in the West Waterway.

Remedial activities were conducted as planned, and cleanup goals were obtained for the first phase of the remedial action. EPA conducted a final inspection on March 7, 2005. The final inspection concluded that construction had been completed in accordance with the remedial design plans and specifications and did not result in the development of a list of uncompleted tasks for the remedial action.

4.4.3 System Operations, Maintenance and Monitoring Plan

The Operations, Maintenance, and Monitoring Plan (OMMP) was approved on September 28, 2006, for LSS-OU7. The goals of the OMMP are to ensure that the remedial actions continue to be protective of human health and the environment. The specific goals are to ensure that:

- The sediment cap continues to isolate toxic concentrations of previously identified COCs in the underlying sediments from marine biota and other biological receptors.
- The sediment cap and the previously dredged open channel area do not become recontaminated with COCs from the underlying sediments or from the uplands adjacent to the LSS-OU7.

The LSS-OU7 is divided into five areas based on characteristics or function. They are the:

- Slope Area
- Open Channel Area
- Beach Area
- Mitigation Area
- Riparian Area

The OMMP requires visual inspections, hydrographic and topographic surveys, and sediment and groundwater monitoring for COCs. Monitoring results will be used to assess cap integrity, sediments quality and source control. Detailed tasks and procedures are described in the OMMP.

Visual inspections are conducted of the riparian buffer, Mitigation Area, and the Beach Area at a very low point in the tidal cycle, approximately - 3 feet.

Hydrographic surveys are evaluated to assess the stability of the Slope Area and Open Channel Area. The survey involves creation of a bathymetric map. Isopachs are produced by comparing results from previous and current bathymetric maps. The isopach illustrates changes in the bathymetry from one year to the next.

The topographic survey, also to evaluate stability, involves the creation of a topographic contour map of the Beach Area of the sediment cap and the Mitigation Area. Isopachs are produced by comparing results from previous topographic surveys with the current survey. The isopach illustrates changes in the topography from one year to the next.

Sediment samples are taken and analyzed for COCs to assess the quality of surface sediments. Sediments remaining in the Lockheed Shipyard Sediments Operable Unit (LSS-OU7) must be protective of human health and the environment. Sediment grab samples are taken to evaluate sediment quality in the Open Channel Area, Slope Area, and Beach Area. Sediment traps were placed to evaluate deposition of contamination from the West Waterway. Therefore, if sediments were found to exceed the SQS, EPA could determine whether the contamination was from cap failure or waterway deposition.

There is a limited amount of sediment data. Within 2 years of placement, all sediment traps were lost, probably due to boat activity. Diver visual inspections have found that sediments suitable for sampling are not found in the Slope Area because of heavy rip rapping and tides and currents that prevent fines from settling in that area. Additionally, chemistry data is not available for Beach Area sediments because suitable sediments are not found in the Beach Area. Fines are swept from the Beach Area by tides and currents.

Monitoring wells were installed along the bulkhead on the land side. Results from analyzing groundwater were to be used to assess the quality of the groundwater entering the West Waterway. It is currently uncertain if the groundwater data collected near the bulkhead is representative of groundwater entering the waterway. Additional discussion on the groundwater monitoring program for LSS-OU7 and LU-OU3 is discussed in Section 6.4.2.

See Table 4-4 for a summary of monitoring requirements, frequency, location, and early warning triggers.

Table 4-4. LSS-OU7, Summary of Monitoring Requirements

Monitoring Method	Monitoring Requirement	Frequency	Management Area	Abnormal Observations
Visual and Photographic	• Inspect bulkheads for instability or breach to upland soil. • Inspect shoreline slopes for erosion. • Inspect beach surface materials. • Probe depth of habitat layer in Mitigation Area. • Photograph from standard locations and any usual observations.	• Annually or more frequently if failure noted, use changes, or in-water construction.	• Beach Mitigation	• Bulkhead leaning or breached. • Shoreline riprap slopes eroded. • Beach materials show unusual changes to surface material or other abnormal observations.
Topographic	• Survey beach with standard upland equipment and provide topographic map with 1-foot contours to 0 feet MLLW.	• Annually or as arranged after consultation.	• Beach Mitigation	• Change in elevation of 1 foot or more (Early Warning Level) from original as-built contours.
Hydrographic	• Muitibeam hydrographic survey from -40 feet MLLW to+1 foot. • Provide contour map with 1-foot contours and combine with topographic survey above to produce isopach.	• Annually for Years 1, 3, and 5 • Every 5 years or as needed for construction or earthquake	• Slope	• Change in depth of 1 foot or more (Early Warning Level) from original as-built contours. • Change in profile suggesting erosion or slope Instability.
Sediment Quality	• Sample sediment traps and grabs located. • Analyze samples for COCs. • Prepare data table and sample location figure.	• Annually or as arranged after consultation.	• Open Channel • Slope	• COCs above 75% of the SQS (Early Warning Levels).
Groundwater Source Control	• Sample groundwater from wells as per Sampling Analysis Plan (SAP). • Analyze samples as per SAP.	• Per SAP or as arranged after consultation.	• T-10/Yard 1 Upland	• As per SAP.
Reporting	• Reports to include procedure for corrective action to any discrepancies and a discussion of the results of any chemical analysis performed.	• Annually for first 2 years followed by every 5 years.	–	**REPORT EMERGENCIES AND EXCEEDANCES OF EARLY WARNING LEVELS**

Remedial action at the LSS-OU7 was completed on February 4, 2005. The OMMP was implemented immediately after the completion of the remedial action to gather monitoring data that would serve as a baseline against which future monitoring results would be compared. The final topographic and hydrographic surveys were taken on February 28, 2005. These surveys demonstrate that the cap met design specifications and will serve as a baseline against comparison to future OMMP surveys. To date, four annual monitoring events have been conducted. The results of the monitoring events are provided in the Table 4-5.

Table 4-5. LSS-OU7, Summary of Monitoring Results

Year	Sediment Chemistry – Open Channel	Sediment Chemistry – Cap Slope Area	Sediment Traps – Cap Slope and Open Channel Area	Beach Area Sediment Chemistry	Topographic Survey – Beach and Mitigation Area	Hydrographic Survey – Open Channel and Cap Slope	Upland Source Control
2006	No exceedances of SQS. Two exceeded early warning levels.	Not enough sediment to perform chemical analysis; one trap missing.	Not enough sediment to perform chemical analysis; one trap missing.	No exceedances of SQS or early warning levels in Beach Area.			No data; monitoring wells improperly screened
2007	One SQS exceedance for Hg but lower than surrounding non-site areas. Two exceeded early warning levels.	One sediment trap sample – no exceedance of SQS, but exceeded early warning level for Hg.	One trap sampled – sediments below SQS; four other traps missing.	No exceedances of SQS or early warning levels.	Not required for Year 2.	Not required for Year 2.	No data; monitoring wells improperly screened
2008	No exceedances of SQS or early warning levels in Open Channel Area.	No data from Cap Slope Area[a]; sediments not suitable for sampling.	No data—all sediment missing; task discontinued.	No data from the Beach Area; sediments not suitable for sampling.	No elevation changes in the Mitigation Area; No significant elevation change in the most of the Beach Area except some elevation gain on the north end of the sediment cap.	No significant change; most areas no change; discrete areas minor fluctuations less than one foot.	No data; monitoring wells improperly screened
2009	No exceedances of SQS or early warning levels in Open Channel Area.	No data from Cap Slope Area[a]; sediments not suitable for sampling.	No data—all sediment missing; task discontinued.	No exceedances of SQS or early warning levels in Beach Area.	Not required for Year 4; required for Year 5.	Not required for Year 4; required for Year 5.	Task discontinued .

[a] Sediment traps were placed to monitor for sediment deposition from the West Waterway. All sediment traps were eventually lost.

Results from the various monitoring events indicate that the cap is stable, that surface sediments in the Open Channel are below the cleanup numbers, and that fine-grained sediments cannot be located for sampling in the Slope and Beach Area. Observations of the Riparian Buffer indicate that the larger shrubs, such as shore pines and alders appear to be healthy, while the smaller vegetation is absent due to damage by geese. Conclusions based on monitoring events are shown below in Table 4-6.

Table 4-6. LSS-OU7, Conclusions Based on Monitoring Events

Year	Open Channel Area	Slope Area	Beach Area	Mitigation Area	Riparian Buffer
2006	No Response Action Required	No Response Action Required	No Response Action Required	No Response Action Required	
2007	No Response Action Required	No Response Action Required	No Response Action Required	No Response Action Required	Larger shrubs appear healthy; smaller vegetation absent.
2008	No Response Action Required	No Response Action Required	No Response Action Required	No Response Action Required	Larger shrubs appear healthy; smaller vegetation absent.
2009	No Response Action Required.	No Response Action Required	No Response Action Required	No Response Action Required	No Response Action Required.

No institutional controls were specified in the ROD, subsequent ESDs, or the CD for the LSS-OU7. Specific institutional controls beyond best management practices and review of permit applications through the USACE have not been implemented nor has an Institutional Controls Study been completed.

4.5 WEST WATERWAY OPERABLE UNIT (WW-OU8)

4.5.1 Remedial Actions

The no action ROD for the West Waterway OU (September 11, 2003) presented the basis for the determination that no CERCLA action was necessary at this OU to protect human health or the environment. The no action ROD did not include any requirements for institutional controls and did not require long-term monitoring. Since no remedial action was selected, there is no information on remedy implementation or operation and maintenance activities.

4.6 TODD SHIPYARDS SEDIMENT OPERABLE UNIT (TSS-OU9)

4.6.1 Remedy Selection

The ROD for the Todd Shipyard Site was signed on November 30, 1996. Remedial Action Objectives (RAOs) were developed as a result of data collected during the Remedial Investigation to aid in the development and screening of remedial alternatives to be considered for the ROD. The RAO for the TSS-OU9 is to reduce concentrations of hazardous substances to levels that will have no adverse effect on marine organisms.

The major components of the remedy selected in the ROD include the following:

1. All sediment exceeding the chemical contaminant screening level of the State of Washington Sediment Management Standards (SMS) and shipyard waste be dredged and disposed of in an appropriate in-water or upland disposal facility.
2. All sediments exceeding the sediment quality standards (SQS) of the SMS will be capped with a minimum of 2 feet of clean sediment.
3. Specification of design criteria for acceptable habitat and to prevent future recontamination.

4. Institution of long-term monitoring and maintenance of the remedy.
5. The extent of dredging of contaminated sediments and waste under piers at the TSS-OU9 will be determined during remedial design based on cost, benefit, and technical feasibility.

Subsequent to the ROD, pre-remedial design studies for the TSS-OU9 better defined the nature and extent of contamination within the OU. The results of these studies indicated that certain elements of the ROD needed to be amended. EPA issued an ESD on December 27, 1999. The purpose of the ESD is to designate the Todd Shipyards Site as an independent operable unit identified as the Todd Shipyards Sediment Operable Unit (TSS-OU9) and to redefine the boundary of the OU identified in the November 1996 ROD based on additional information gathered during two remedial design investigations associated with this OU.

On April 7, 2003, EPA issued a second ESD. The primary changes documented in this ESD were to:

(1) Further define the selected remedial action for the under-pier areas;

(2) Establish confirmation numbers characteristic of contamination present in the West Waterway for the purpose of defining the Todd Shipyard Sediments Operable Unit (TSS-OU9) boundary;

(3) Adjust the TSS-OU9 boundary based on the use of confirmation numbers;

(4) Summarize the long-term monitoring, maintenance and operational requirements for TSS-OU9;

(5) Define "predominately abrasive grit blast (AGB)"; and

(6) Identify the disposal option.

4.6.2 Remedy Implementation

In an Administrative Order on Consent (AOC) signed with EPA on April 25, 2000, Todd Shipyards agreed to perform the remedial design (RD) for implementing the remedy in conformance with the ROD as modified by the 1999 ESD. The RD was approved by EPA on May 25, 2004. A Consent Decree (CD) between EPA and Todd was approved by the Court on July 21, 2003, to perform the remedial action (RA).

The RA was conducted in two phases. Phase 1 was completed at the end of February 2005, and Phase 2 was completed in February 2007. The first phase of remedial construction efforts was focused along the north end of the TSS-OU9 and included pier demolition, dredging, and disposal of contaminated sediments and capping. The activities for this phase were initiated on July 5, 2004, and were completed on February 25, 2005. The major components of this phase of the RA were the following:

- Completed demolition and disposal of side-launch shipways located along the Northeast Shoreline of SMA 1 and Pier 2 located in SMA 8.
- Completed dredging and disposal of contaminated sediment and shipyard debris in SMAs 1, 2, 3, 4, and 5, located on the north side of the Todd property.
- Completed placement of in-water fill, including reconstruction of the Northeast Shoreline slope in SMAs 1 and 2; filling of subtidal depressions in SMAs 3, 5, and 7; and placement of boundary sand in SMAs 1 and 5.

- Completed placement of under-pier cap material at Pier 4 North, Pier 5, Pier 6, and Pier 6 Platform.
- Initiated, but did not complete, dredging and disposal of contaminated sediment in SMAs 7, 8, and 9.

During this period, 166,192 cubic yards of contaminated sediments were dredged and transported to an approved upland facility for disposal (see Table 4-7).

Table 4-7. TSS-OU9, Amount of Dredged Material by Sediment Management Area (SMA)

SMA	Dredged Material Weight in Tons	Estimated Dredge Material Volume in Cubic Yards
1 and 2	50,713	35,217
3	77,619	53,902
4	52,524	36,475
5	27,687	19227
6	0	0
7	0	0
8	27,679	19,222
9	3,095	2,149
Total:	**239,317**	**166,192**

Under-pier capping was implemented using special equipment consisting of a throwing conveyor mounted on a series of modular floats, a barge-mounted derrick crane, and a series of flat-decked material barges. Table 4-8 shows the total under-pier square footage capped per pier.

Table 4-8. TSS-OU9, Amount of Cap Material Placed by Pier

Pier	Placement Area in Square Feet
4N	42,488
5	66,015
6	29,700
6P	12,700
Total:	**150,903**

Placement techniques, using the throwing conveyor, were developed through implementation of a test program that took place in SMA 2, on the eastern side of Pier 6. Diver survey results of the underwater areas capped during the test program verified that the placement equipment and techniques met all specified criteria. The design criteria for capping under pier structures with timber piling was to place 1 foot (average thickness) of sand and to place 3 feet (average thickness) for pier structures supported by concrete piling. The capping test at Pier 6, a timber supported pier, was considered by EPA to be a worse case test because Pier 6 has a much greater density of piles than concrete pile supported piers.

A total of 45 sediment samples were collected from the post-dredge surface of SMAs 1-7 to evaluate compliance with the design criteria. Two of these samples were submitted for bioassay testing and evaluated for compliance using the SMS biological criteria. One of the bioassay locations did not pass the SMS biological criteria; this area has been addressed by placement of a permanent sediment cap. The remaining 43 samples were compared to the SQS chemical criteria to evaluate compliance.

Out of 423 chemical analytical results, from 43 samples, 6 samples exceeded the SQS for mercury only, which represents 98.6 percent of all sample analytical results being less than the SQS chemical criteria (see Table 4-9).

Table 4-9. TSS-OU9, Confirmation Sampling Locations, Results, and Remedial Action for Samples Exceeding the Compliance Criteria

Sampling Locations		Compliance Criteria	Sampling Results	Remedial Action Taken
SMA 1	TSP-01-01	mercury – 0.41 mg/kg	0.68 mg/kg	none
SMA 2	TSP-02-06	mercury – 0.41 mg/kg	0.71 mg/kg	ENR
	TSP-02-08	mercury – 0.41 mg/kg	0.48 mg/kg	ENR
SMA 3	TSP-03-02	mercury – 0.41 mg/kg	0.85 mg/kg	ENR
	TSP-03-06	mercury – 0.41 mg/kg	1.04 mg/kg	ENR
	TSP-03-07	mercury – 0.41 mg/kg	0.66 mg/kg	ENR

All mercury exceedances were below the 90th percentile for mercury present in the West Waterway based on bioassays. A No Action determination was made for the West Waterway Operable Unit of the Harbor Island Superfund Site.

Water quality monitoring during in-water remedial action was conducted according to the Water Quality Certification. Visual turbidity monitoring was performed during demolition of over-water structures and intensive and routine water quality monitoring was performed during dredging and barge dewatering and filling/capping operations. Results of these monitoring events indicate that water quality remained within marine quality standards throughout the monitored events.

A Fish Coordination Plan was developed by Todd in consultation with EPA and affected Indian Tribes. There are two Treaty Indian Tribes that have reserved fishing rights in the lower Duwamish River including the area of the Todd sediment remediation. The Muckleshoot and Suquamish cooperatively fish in these waters. Because in-water demolition, dredging, and capping activities would be occurring at the same time that Tribal fishing would be occurring, a Tribal Fishing Coordination Plan (Fish Coordination Plan) was developed jointly with the affected Tribes and Todd. The objectives of the Fish Coordination Plan were to:

1. Reduce the potential for conflicts between in-water construction operations and tribal fishing through effective communications and schedule planning.
2. Rapidly address any fishing equipment damaged as the result of construction operations within or adjacent to the site area.
3. Coordinate future construction activity (as practical) to reduce potential for further damage to fishing equipment.

According to the Fish Coordination Plan, ongoing communications between the Todd contractors and the Tribes successfully minimized conflicts between in-water construction and tribal fishing activities despite a high level of fishing activity and record catches in the Waterway.

Remedial activities were conducted as planned, and cleanup goals were obtained for the first phase of the remedial action. EPA conducted a pre-final inspection on March 7, 2005. The pre-final inspection concluded that construction had been completed in accordance with the remedial design plans and specifications and did not result in the development of a punch list for the first phase of remedial action.

Remedial construction activities for the Phase 2 started on July 5, 2005, and all remedial action construction activities for the TSS-OU9 were completed in spring of 2006. The second phase of remedial construction efforts were focused along the west side of the OU, and included pier demolition, dredging and disposal of contaminated sediments, and capping.

The major components of Phase 2 RA were the following:

- Dredging in SMA 6, SMA 8 (where the initial overburden dredging was conducted in 2004), and SMA 9.
- Demolition of Pier 4S.
- Construction of habitat bench in SMA 6.
- Capping below Piers 1, 2P, 3, and outer reaches of building ways.

4.6.3 System Operation/Operation and Maintenance

An Operation, Maintenance, and Monitoring Plan (OMMP) for the TSS-OU9 was approved by EPA on October 22, 2007. The goals of the OMMP are to ensure that the remedial actions continue to be protective of human health and the environment. The specific goals are to ensure that:

- The sediment cap continues to isolate toxic concentrations of previously identified chemicals of concern (COCs) in the underlying sediments from marine biota and other biological receptors; and
- The sediment cap and the previously dredged open channel area do not become recontaminated with COCs from the underlying sediments or from the uplands adjacent to the TSS-OU9.

For the OMMP, the TSS-OU9 was divided into four areas based on characteristics or function. They are the:

- Under-Pier Capped Area
- Northeast Shoreline Sediment Cap
- Western Shoreline Habitat Bench
- Open Water Dredged Area

Annual OMM monitoring (physical integrity monitoring) will occur at the Under-Pier Capped Areas, the Northeast Shoreline Sediment Cap, and the Western Shoreline Habitat Bench. The Open Water Dredged Area would be evaluated during the Five-Year review. Visual surveys will be conducted to assess the:

- Physical integrity monitoring of under-pier cap areas, with contingencies for maintenance of the caps and potential sampling for COCs in areas adjacent to the piers if erosion of cap material has occurred.
- Physical integrity monitoring of the riprap along the Northeast Shoreline in SMA 2 to ensure stability of the sediment cap, with contingencies for maintenance of the cap if erosion of cap material has occurred.
- Physical integrity monitoring of the habitat bench along the Western Shoreline in SMA 6 to ensure the stability of the habitat mix substrate, with contingencies for maintenance of the habitat mix substrate if erosion of this material has occurred.

Early warning standards were developed to signal potential cap failure. Observations of complete erosion of the sand cap along a transect would trigger additional action to assess the extent of erosion and if necessary additional remedial actions. Tables 4-10 through 4-12 provide descriptions regarding the physical integrity monitoring program for these three general areas. Detailed tasks and procedures are described in the OMMP.

Table 4-10. TSS-OU9, Visual Inspections for the Under-pier Capped Area

Type of Monitoring	• Visual diver survey of under-pier sand capped areas. Total of 17 transects to be surveyed.
Schedule/ Frequency	• Baseline survey (Year 0) in fall 2007 • Monitoring surveys in Year 1 (2008), Year 2 (2009), and Year 4 (2011). • Subsequent monitoring survey in Year 9 (2016) if sand cap material remains stable over the first three monitoring surveys. • Supplemental monitoring survey within 60 days after an earthquake that causes liquefaction of soils or building damage, at or near the site (magnitude 6.0 or greater).
Documentation	• Log and audio/video recording of observations such as the substrate type and coverage of sand cap, unusual erosion or accretion of material, presence of debris or unusual materials that are not part of the sand cap. Detailed observations to be made every 10 feet along each transect. • For the Baseline Survey: Data tables including sediment grab sample grain-size distribution results and a figure showing the sample locations. Two samples will be collected along each transect. • For the Monitoring Surveys: Data tables including sediment grab sample grain-size distribution results and a figure showing the sample locations, if collected. Grab samples will only be collected if the diver is unable to visually determine the type of substrate. • Under-Pier Physical Integrity Monitoring Reports after each survey Event. • Written notification to USEPA will be made within 30 days of observations of under-pier capped areas that have complete erosion of the sand cap.
Comparative Data	• Previous observations and video recordings. • Baseline grab sample grain-size distributions.
Threshold for Action	• These under-pier areas have been covered with either a 1-foot layer of sand (Piers 1A, 1, 2P, 3, 6, and 6P and within the over-water areas of the building berth) or a 3-feet layer of sand (Piers 4N and 5). • Movement of the cap material may decrease or increase the cap thickness at various locations. Such movement was expected in the design. Observation of complete erosion of the sand cap along a transect would trigger investigation into the size of the area affected, evaluation of the cause, and potential action.

Table 4-11. TSS-OU9, Visual Inspections for the Northeast Shoreline Sediment Cap Area

Type of Monitoring	• Visual diver/surveyor survey of the Northeast Shoreline Sediment Cap for baseline and routine monitoring surveys. One transect to be surveyed (refer to Figure 3.1). • Visual shoreline survey of the riprap on the cap for supplemental monitoring surveys at low tide.
Schedule/ Frequency	• Baseline survey (Year 0) in fall 2007. • Monitoring surveys in Year 1 (2008), Year 2 (2009), and Year 4 (2011). • Subsequent monitoring survey in Year 9 (2016) if riprap remains stable over the first three monitoring surveys. • Supplemental monitoring survey during a low tide within 60 days after a severe storm or an earthquake or during a tide which is at or below elevation minus 2 feet MLLW during daylight hours, whichever is sooner. Note that the visual shoreline survey may be changed to a visual diver survey if a sufficiently low tide is not available during daylight hours.
Documentation	• Log and audio/video recording of observations such as the substrate type and coverage of the riprap, unusual erosion or accretion of material, presence of debris or unusual materials that are not part of the riprap. Detailed observations to be made every 10 feet along each transect. • Physical Integrity Monitoring Reports after each survey event. • Written notification to USEPA will be made within 30 days of observations of areas of the Northeast Shoreline Sediment Cap that have complete erosion of the riprap.
Comparative Data	• Previous observations and video recordings.
Threshold for Action	• For the Northeast Shoreline Sediment Cap, a 3-foot riprap layer was placed over a minimum 2-foot-thick isolation layer of gravelly sand. • Observation of erosion of the riprap along the transect would trigger investigation into the size of the area affected, evaluation of the cause, and potential action.

Table 4-12. TSS-OU9, Visual Inspections for the Western Shoreline Habitat Bench

Type of Monitoring	• Visual diver survey of the Western Shoreline Habitat Bench for baseline and routine monitoring surveys. Total of 3 transects to be surveyed. • Visual shoreline survey of the habitat bench for supplemental monitoring surveys at low tide.
Schedule/ Frequency	• Baseline survey (Year 0) in fall 2007. • Monitoring surveys in Year 1 (2008), Year 2 (2009), and Year 4 (2011). • Subsequent monitoring survey in Year 9 (2016) if Type 2 Habitat mix remains stable over the first three monitoring surveys. • Supplemental monitoring survey during a low tide within 60 days after a severe storm or an earthquake or during a tide which is at or below elevation minus 2 feet MLLW during daylight hours, whichever is sooner. Note that the visual shoreline survey may be changed to a visual diver survey if a sufficiently low tide is not available during daylight hours.
Documentation	• Log and audio/video recording of observations such as the substrate type and coverage of habitat mix, unusual erosion or accretion of material, presence of debris or unusual materials that are not part of the habitat mix. Detailed observations to be made every 10 feet along each transect. • Physical Integrity Monitoring Reports after each survey event. • Written notification to USEPA will be made within 30 days of observations of areas on the habitat bench that have complete erosion of the habitat mix.
Comparative Data	• Previous observations and video recordings. • Grain-size distribution of the Type 2 Habitat Mix.
Threshold for Action	• At the habitat bench, a 3-foot-deep layer of Type 2 Habitat Mix was placed over a minimum 2-foot-thick sand cover. • Movement of the habitat mix may decrease or increase the thickness of the habitat mix at various locations. Observation of complete erosion of the habitat mix along a transect would trigger investigation into the size of the area affected, evaluation of the cause, and potential action.

Post-construction sediment sampling and survey data were used to verify that the completed remedial action (dredging and capping) met design specifications. These data were also used to establish a baseline (Year 0) against which future monitoring results would be compared.

The OMMP was approved in August 2007 after completion of the remedial action. The RPM has reviewed the OMMP Baseline Monitoring Report (Year 0) and two annual OMM Reports (Years 1 and 2), compared results with baseline results, and has determined that no Response Actions are necessary because there is no evidence that significant erosion of cap material had occurred. The presence of shell debris and silts indicate that the area has not been subject to erosional forces. The results of the monitoring events are provided in Table 4-13.

Table 4-13. TSS-OU9, Summary of Monitoring Results

Year	Under-Pier Capped Area	Northeast Shoreline Sediment Cap Area	Western Shoreline Habitat Bench
Baseline	Sand cap remained in place; early warning actions not triggered. Grain size assessment verifies the existence of cap material. Shell debris and/or silt are beginning to build up on cap in a number of locations.	No disturbance of riprap and habitat mix. Heavily colonized by algae and plants.	No disturbance of cap and habitat mix. Heavily colonized by algae and plants.
2008	Sand cap remained in place; early warning actions not triggered. Continued shell debris and/or silt build-up on cap in a number of locations.	No disturbance of riprap and habitat mix. Heavily colonized by algae and plants.	No disturbance of cap and habitat mix. Heavily colonized by algae and plants.
2009	Sand cap remained in place; early warning actions not triggered. Continued shell debris and/or silt build-up on cap in a number of locations.	No disturbance of riprap and habitat mix. Heavily colonized by algae and plants.	No disturbance of cap and habitat mix. Heavily colonized by algae and plants.

Results from the various monitoring events indicate that the cap is stable with build-up of shell debris and/or silts over time. Table 4-14 below provides conclusions based on the monitoring events.

Table 4-14. Conclusions Based on Monitoring Events

Year	Under-Pier Capped Area	Northeast Shoreline Sediment Cap Area	Western Shoreline Habitat Bench
2007	No Response Action Required.	No Response Action Required.	No Response Action Required.
2008	No Response Action Required.	No Response Action Required.	No Response Action Required.

EPA has required that chemical sampling of the Open Water Dredged Area be conducted for this five-year review. However, that data will not be available until September 2010. At a minimum, depending on the results of the sampling, chemical monitoring may be needed of the Open Water Dredged Area.

No institutional controls were specified in the ROD, subsequent ESDs, or the CD for the TSS-OU9. Specific institutional controls beyond best management practices and review of permit applications through the USACE have not been implemented nor has an Institutional Controls Study been completed.

4.7 EAST WATERWAY OPERABLE UNIT (EW-OU10)

4.7.1 Remedial Actions

No ROD has been written for this OU. In 2004–2005, the Port of Seattle conducted a non-time-critical removal action for highly contaminated sediments on the East Waterway. The removal action was implemented under the authority of an Action Memorandum (2003). The following actions were completed under the Action Memorandum:

1. Dredging 180,000 cubic yards of contaminated sediment unsuitable for open-water disposal and 67,000 cubic yards of sediment suitable for open-water disposal.
2. Dewatering sediments not suitable for open-water disposal at an upland staging area and disposing of the dewatered sediments at an upland landfill.

In 2005, it was determined that the dredging did not reach SQS sediment standards after sediment removal so a 6-inch layer of clean sand was placed over the surface to protect benthic organisms from residual contaminants. Recontamination monitoring in 2006, 2007, and 2008 does reveal the presence of PCBs and Hg above sediment management standards. A supplemental remedial investigation and feasibility study is underway. Currently, sampling has been completed for surface sediment, subsurface sediment, surface water, benthic tissue, clams, geoduck, and fish. Concurrent sediment transport analysis and source evaluation is also underway in order to ascertain the potential for cleanup areas to recontaminate following future remedial action.

5. PROGRESS SINCE THE SECOND FIVE-YEAR REVIEW

5.1 SOIL AND GROUNDWATER OPERABLE UNIT (S&G-OU1)

5.1.1 Protectiveness Statements from Last Review

The protectiveness statement in the last Five-Year Review (2005) stated:

> *The remedy at this OU is expected to be protective of human health and the environment upon completion, and in the interim, exposure pathways that could result in unacceptable risks are being controlled.*

5.1.2 Status of Recommendations and Follow-Up Actions from Last Review

Recommendations presented in the last Five-Year Review (2005):

1. Full Implementation of Phase I long-term groundwater monitoring is scheduled to begin in October 2005. The plan also calls for the integration of several monitoring programs to be coordinated and consolidated among the various PRPs and OUs. Additional groundwater monitoring points are anticipated as the planning for a Phase II gets underway.

   Status: Ongoing. The S&G-OU1 long-term monitoring plan (Revision 3 plan) has been approved by EPA, and new/replacement wells have been installed. The first quarterly monitoring event for the new wells was in June 2009. After four quarters, the data will be evaluated to determine which wells will be included in the final long-term monitoring program. Semi-annual monitoring of the existing wells continues.

2. Continue TPH soil contamination cleanup at Todd Shipyard.

   Status: Ongoing. In 2009, a modification to the LNAPL removal system at Todd Shipyards was completed to address the remaining LNAPL. The revised system will contain six recovery wells (three new and three existing) and focus on extraction near the Aluminum Plant Building. At of the end of February 2009, over 300,000 gallons of LNAPL have been recovered, and it is estimated that 36,000 to 50,000 gallons remain. Since the last Five-Year Review, an additional Geoprobe investigation was implemented to define the extent of remaining LNAPL. The investigation determined that areas of recoverable LNAPL remained near the aluminum shop, and the remedial system was modified. In addition, a soil "Hot Spot" containing a heavy NAPL was identified. Once the nature and extent is determined, remedial options for this "Hot Spot" will be developed.

3. Site specific institutional controls (ICs) need to be developed and implemented.

   Status: Ongoing. As part of this five-year review, an ICS has been received from the Harbor Island Settling Defendants that includes the Todd upland property. More effort is needed to implement ICs that would address contaminated groundwater. EPA is currently working with the Harbor Island Settling Defendants that include Todd Shipyard, to fulfill the terms and conditions in the Consent Decree regarding IC implementation. ICs are expected to be completely implemented in 2012.

5.1.3 Results of Implemented Actions

Results of Implemented Actions:

1. The EPA-approved groundwater monitoring plan is a culmination of numerous discussions and plan revisions between the S&G-OU1 Steering Committee and EPA. The initial monitoring plan, herein called the Revision 1 plan, included a conductivity profile assessment and the installation of 16 new wells in 2005 (RETEC 2004). The Revision 1 plan required quarterly monitoring of the 16 new wells and 4 existing wells for 2 years and began in September 2005. A revised monitoring plan (Revision 2 plan) was developed in 2008 to address EPA concerns regarding 1) the location of well screen intervals and their ability to monitor freshwater emanating from the interior of the island, and 2) the potential for utility backfill to act as a preferential pathway for groundwater to discharge to surface water (ENSR 2008b). After addressing additional comments from EPA concerning well screen locations and installation of monitoring wells in the interior of the island, the Revision 3 plan was approved in 2009 (ENSR 2008c).
2. The LNAPL system modifications were completed in 2009. Data from the new system has not been reviewed to date.
3. An ICS has been submitted to EPA by the Harbor Island Settling Defendants. EPA has reviewed this study and determined that more effort is needed by the Responsible Parties in implementing ICs that address remaining contamination that result in restricted use of the upland properties. EPA will work with the Responsible Parties to ensure that the appropriate restrictive covenants are in place on all parcels. This effort is expected to continue into 2012.

5.1.4 Status of Other Prior Issues

There are no other prior issues.

5.2 TANK FARMS OPERABLE UNIT (TF-OU2)

5.2.1 Protectiveness Statements from Last Review

The protectiveness statement in the last Five-Year Review (2005) stated:

> *The remedy at this OU is expected to be protective of human health and the environment upon completion, and in the interim, exposure pathways that could result in unacceptable risks are being controlled.*

5.2.2 Status of Recommendations and Follow-Up Actions from Last Review

The following information was developed with information provided by the Washington State Department of Ecology that has the lead regulatory authority for this OU.

Recommendations presented in the last Five-Year Review (2005):

1. Remedial actions not determined at this time could be implemented in localized areas of the TF-OU2 where minor free product and/or dissolved contaminant levels persist above standards.

   Status: Ongoing. Additional remedial actions have been completed at TF-OU2 since the last Five-Year review. These include "hot spot" removals and the design and construction of an air sparging and SVE system at the KM facility and an SVE system at the BP facility.

5.2.3 Results of Implemented Actions

Results of Implemented Actions:

1. TPH contaminated soil was removed at the Shell facility during site upgrades and construction. Access to TPH contaminated soil identified during the RI was allowed due to the removal of several large fuel pipelines at the Shoreline Manifold area and the removal of above-ground piping near Tank 80000. An air sparging and SVE system was installed along the western boundary of A Yard in the KM facility to prevent migration of petroleum contaminated groundwater outside of the property boundaries. An SVE system was also installed along the southern property boundary of Plant 1 at the BP facility.

5.2.4 Status of Other Prior Issues

Status of Other Prior Issues:

1. Continue groundwater monitoring. The number of wells monitored and the frequency will be reduced as appropriate.

Monitoring requirements, including the frequency and numbers of analytes, are reduced on an individual well basis. Analytes are dropped if cleanup levels have been met for a significant time. Since 2005, no wells have been dropped from the monitoring program and five new wells have been installed.

5.3 LOCKHEED UPLAND OPERABLE UNIT (LU-OU3)

5.3.1 Protectiveness Statements from Last Review

The protectiveness statement in the last Five-Year Review (2005) stated:

The ROD remedy for this OU has been completed and the OU deleted from the NPL. The protective surface soil cap upgrade by diverting surface runoff will provide additional protection to the marine environment. The remedy at this OU is expected to be protective of human health and the environmental when maintenance issues are addressed, and in the interim, exposure pathways that could result in unacceptable risks are being controlled.

5.3.2 Status of Recommendations and Follow-Up Actions from Last Review

Recommendations presented in the last Five-Year Review (2005):

1. The PRP for the Lockheed Upland area needs to establish positive run-on/run-off controls for the property. Plans have been drafted, but the construction has not yet occurred.

   Status: Ongoing. The Port of Seattle has been approved to redevelop the site. The Terminal 10 Utility Infrastructure Upgrade Project includes regrading the entire site and installing a storm sewer system, which will be connected to the City of Seattle storm sewer system.

5.3.3 Results of Implemented Actions

Results of Implemented Actions:

1. In 2008, the Port of Seattle was approved to redevelop the site. The Terminal 10 Utility Infrastructure Upgrade Project includes demolishing pavement in some areas and removal of any contaminated soil identified in those areas, regrading the entire site, and installing a storm sewer system, which will be connected to the City of Seattle storm sewer system. After the completion of this work, the entire site will be paved and lighting and fencing will be installed. If any contamination remains on-site above containment levels identified in the ROD following the completion of the redevelopment, a revised inspection and maintenance plan will be required. As of May 2010, these facility upgrades are still in the 60 percent design phase.

5.3.4 Status of Other Prior Issues

There are no other prior issues.

5.4 LOCKHEED SHIPYARD SEDIMENT OPERABLE UNIT (LSS-OU7)

5.4.1 Protectiveness Statements from Last Review

The Protectiveness Statement made in the 2005 five-year review stated that upon completion of the remedy EPA expected that the LSS-OU7 would be protective of human health and the environment. The remedy has now been constructed.

5.4.2 Status of Recommendations and Follow-Up Actions from Last Review

There were no recommendations.

5.4.3 Results of Implemented Actions

There were no follow-up actions.

5.4.4 Status of Other Prior Issues

There are no prior issues.

5.5 WEST WATERWAY OPERABLE UNIT (WW-OU8)

5.5.1 Protectiveness Statements from Last Review

The protectiveness statement in the last five-year review was:

This OU is considered protective of human health and the environment and a No Action ROD was written for this OU.

5.5.2 Status of Recommendations and Follow-Up Actions from Last Review

The no action ROD for the West Waterway OU (September 11, 2003) presented the basis for the determination that no CERCLA action was necessary at this OU to protect human health or the environment. The no action ROD did not include any requirements for ICs and did not require long-term monitoring. Since no remedial action was selected, a five-year review is not required. Thus, the second five-year review for the Harbor Island Superfund site did not include any recommendations or follow-up actions for the West Waterway OU, and there is no relevant information for this section.

5.5.3 Results of Implemented Actions

Due to the No Action ROD, no actions were implemented.

5.5.4 Status of Other Prior Issues

Due to the No Action ROD, no prior issues were identified.

5.6 TODD SHIPYARDS SEDIMENTS OPERABLE UNIT (TSS-OU9)

5.6.1 Protectiveness Statements from Last Review

The Protectiveness Statement made in the 2005 five-year review stated that upon completion of the remedy EPA expected that the TSS-OU9 would be protective of human health and the environment. The remedy has now been constructed.

5.6.2 Status of Recommendations and Follow-Up Actions from Last Review

There were no recommendations.

5.6.3 Results of Implemented Actions

There were no follow-up actions.

5.6.4 Status of Other Prior Issues

There are no prior issues.

5.7 EAST WATERWAY SEDIMENTS OPERABLE UNIT (OU10)

Since the last five-year review, a supplemental remedial investigation (SRI) and feasibility study (FS) is underway. This SRI/FS includes sampling for sediments and tissue, surface sediment, sediment transport and source evaluation. In addition, the United States Coast Guard (USCG) has submitted an Environmental Assessment for the Berth Bravo in Slip 36. More information on how this action will impact existing contaminated sediments and future remedial actions is necessary before the USCG can proceed with the replacement of the Berth Bravo pier.

All field sampling has been completed, which includes sediment, fish, and shell fish tissue. The SRI/FS is expected to be completed in 2012, and a cleanup decision for East Waterway made in 2013. The next five-year review is expected to include the East Waterway cleanup decision with the protectiveness evaluation.

6. FIVE-YEAR REVIEW ADMINISTRATIVE COMPONENTS (SITE WIDE)

The PRPs were notified of the initiation of the Five-Year Review in summer 2009. Separate meetings occurred with the Harbor Island Settling Defendants and Lockheed Martin Corp. The Five-Year Review team was lead by Ravi Sanga of EPA, Remedial Project Manager (RPM). Sharon Gelinas, Hydrogeologist from the U.S. Army Corps of Engineers (USACE), Seattle District, assisted with the S&G-OU1 and LU-OU3. Reviews for the other OUs were as follows: LSS-OU7 and TSS-OU9: Lynda Priddy, EPA Project Manager; West Waterway: Karen Keeley, EPA Project Manager; East Waterway: Ravi Sanga; and Tank Farms OU2: Roger Nye with the Washington Department of Ecology.

EPA met with the S&G-OU1 Steering Committee on October 5, 2009, and LU-OU3 representatives on October 26, 2009, to discuss data needs for the Five-Year Review.

From August 2009 to July 2010, the review team established the review schedule. Those components included:

- Community Involvement;
- Document Review;
- Data Review;
- Site Inspection;
- Local Interviews; and
- Five-Year Review Report Development and Review.

6.1 COMMUNITY/STAKEHOLDER INVOLVEMENT

Activities to involve the community in the Five-Year Review included preparing and running a public notification of the Five-Year Review in the Seattle Times, August 31, 2009.

On November 16, 2009, a briefing on the Harbor Island Five-Year Review was given to the affected federally recognized Native American tribes (Muckleshoot and Suquamish Indian Tribes) who use the East Waterway and West Waterway as part of their tribal usual and accustomed fishing area.

In addition, a Stakeholder Meeting on the Harbor Island Five-Year Review was held on December 17, 2009, for the Public Interest Groups and Natural Resource Trustees.

6.2 SOIL AND GROUNDWATER OPERABLE UNIT (S&G-OU1)

6.2.1 Document Review

This Five-Year Review consisted of a review of relevant documents as summarized in the References section at the end of this report. Documents can be reviewed at EPA Region 10 Superfund Records Center. Applicable groundwater and surface water cleanup standards were also reviewed.

6.2.2 Data Review

Institutional Controls. As stated in the ROD, ICs were required to 1) provide long-term maintenance of new and existing caps, 2) warn future property owners of remaining contamination under capped areas on their property, and 3) specify procedures for handling and disposal of excavated contaminated soil if future excavation is necessary.

A review of ICs associated with each property within the S&G-OU1 was conducted by TechSolv, the consultant for the S&G-OU1 Settling Defendants. The purpose of this review was to ensure that ICs are appropriate, in place, and are effective across the site. EPA requested the following information to document the ICs:

1. Documentation of all ICs in place for the S&G-OU1.
2. Copies of all instruments that conveyed any interest in any portion of the S&G-OU1 since 15 days of entry of the Consent Decree, with the required provision of access and necessary restrictions or covenants.
3. Figures showing parcel boundaries and survey information.
4. Current information about all lessees or users of the S&G-OU1.
5. An Institutional Control Study (ICS) that must provide, at a minimum: a title search; copies of encumbrances; evaluation of whether encumbrances negatively impact existing controls; evaluation of compliance with ICs; evaluation of any current human or potential human or ecological exposures; evaluation of any threatened or existing inconsistencies that could lead to exposures; evaluation of the protectiveness and effectiveness of all ICs; evaluation of all instruments, any proposed additional controls; certification that each CD and all other instruments were properly recorded; certification that all property transfer deeds contain obligation to provide access and maintain ICs and require all future transfers to do so; and recommendations.

EPA has reviewed the ICS submitted by the Harbor Island Settling Defendants and concluded that more work is needed from the Responsible Parties in establishing restrictive covenants that account from the contamination left behind on the upland and that address (1 through 5) above. Currently, only two parcels contain covenants that address the contamination left behind on the upland properties. Additionally, ICs that restrict groundwater use need to be addressed.

Cap Inspections and Maintenance

The Harbor Island Settling Defendants are responsible for annual inspection and maintenance of all upland asphalt caps on Harbor Island with the exception of the asphalt cap on Lockheed Upland that is the responsibility of Lockheed Martin. The main objective for the cap is to protect site workers from contaminated soil; a secondary objective is to reduce infiltration of rainwater, thus limiting contaminant transport to ecological receptors in the waterways. Consistent inspections and maintenance are necessary to ensure that the cap remains protective of human health and the environment. Of the six properties within the S&G-OU1 that contain environmental caps, only two have submitted reports on a consistent basis. The Port of Seattle inspections for Terminal 18 have been completed annually since 2007 in accordance with the Design Set No. 2 Capping Implementation Report (RETEC 2006). Fisher Mills/King County has submitted inspections in accordance with Design Set 1B Capping Remedial Action Implementation Report (RETEC 1998) since 2001. The remaining properties, the Dutchman, LLC; Harbor Island Machine Works, Inc.; Duwamish Properties LLC; and Union Pacific Railroad Company do not currently have inspection reports on file. Duwamish Properties LLC is planning an expansion of their existing facility. EPA was

contacted in October 2009 to discuss the project and will review the Stormwater Pollution Protection Plan (SWPPP) to ensure that human health and the environment are protected during construction.

A summary of the reported cap inspections and maintenance is as follows:

- The first cap inspection in 2007 for Terminal 18 noted several areas in need of repair, including potential cap settlement in an area of standing water and potholing/cracking. A limited-scope inspection was completed in 2008 in the areas previously identified as needing repairs prior to the completion of the repairs (AECOM 2008b). The 2009 report identified the same areas as needing repairs. Repairs are to be completed prior to the 2010 inspection.
- Cap inspections at the Fisher Mills/King County revealed a sinkhole that was repaired in 2005 and a depression that was repaired in 2006. There has been no reported damage to the cap since then.

Todd Shipyards LNAPL Recovery. In 2008, a Geoprobe investigation was completed to define the extent of the remaining LNAPL, particularly near/beneath the Aluminum Shop Building, and to correlate the concentration of LNAPL found in the unsaturated zone with soil observations made during the investigation. The findings as presented in the Geoprobe Investigation Results Report (Floyd | Snider 2008) are as follows:

- Heavy petroleum was identified in three soil borings on the eastern portion of the property. Additional investigations are necessary to determine the extent of the petroleum and potential remedial actions for this unsaturated soil "hot spot."
- Areas of recoverable LNAPL remain, with the main portion in the vicinity of the west portion of the aluminum shop. The remaining volume of LNAPL was estimated to be between 36,000 and 50,000 gallons using a percent saturation between 25 and 35 percent (Floyd | Snyder, 2009b).
- Variability of LNAPL saturation within a soil core in combination with tidal effect leads to a poor correlation between the "true" thickness of the LNAPL as observed in the soil cores and that observed in the adjacent wells or piezometers.

An LNAPL system modification was designed to focus on the removal of the remaining LNAPL beneath the Aluminum Shop Building. The modified LNAPL system includes installation of three new recovery wells, FW-19, FW-20, and FW-21, and continued operation of three existing wells FW-3, FW-17, and FW-18. This modified extraction system is shown on Figure 6-1 (located at the end of this document) and the areal extent of the remaining LNAPL is shown on Figure 6-2 (located at the end of this document). The new recovery wells were installed in late 2009. More data expected in 2010 will ascertain the performance of these wells on the ultimate performance of the extraction system as a whole.

The new system modification will address the remaining LNAPL at Todd Shipyards. Historically, LNAPL thickness in monitoring wells has been used to determine when recoverable LNAPL is no longer present. The endpoint for recovery is related to the saturation of remaining LNAPL and can be defined as the point at which the LNAPL saturation has declined to a point in which the remaining LNAPL is immobile and unrecoverable even under steep hydraulic gradients" (i.e. residual saturation). After discussion with EPA, Todd Shipyards has proposed the following procedure to determine when LNAPL recovery will cease:

- Evaluation will occur on a well by well basis based on the LNAPL recovery rates over the life of the well.

- Active recovery will cease when recovery reaches an asymptote or rates are low enough to begin causing excessive maintenance issues for a period exceeding 6 months. The asymptote has typically been reached when the LNAPL thickness is less than 0.25 foot. When this level is achieved, Todd Shipyards will begin an additional evaluation.
- The additional evaluation includes attempting to increase recovery rates by altering water levels and vacuum rates for 3 months. If no increase occurs, then Todd Shipyards will implement passive recovery if feasible. If an increase occurs, then the well will be operated using the new conditions.
- After recovery is complete, Todd Shipyards will begin rebound monitoring.

Long-Term Groundwater Monitoring

Groundwater Flow

The conceptual model of groundwater flow on Harbor Island was based on data collected during the RI in the mid-1990s. The current site conceptual model, while similar to the original, has led to modifications of the groundwater monitoring program on the island. The most important components of the conceptual model along with modifications based on recent characterization work are listed below:

Original Conceptual Model (1990s)	Modifications
Groundwater behaves as a single hydrostratigraphic unit of freshwater floating on a base of saline water.	A shallow saline water interval has been identified at the margins of the island where bulkheads are not present (or fail to significantly impede flow). Freshwater from the interior of the island discharges below this shallow saline interface.
Recharge occurs primarily through precipitation and infiltration from utility lines.	Recharge has likely decreased substantially due to the increase in impervious surface at Terminal 18.
Groundwater flows mainly outward from the interior of the island in a radial pattern and discharges to the waterways.	The center of the island appears to be drained by a major sewer line, which has caused a groundwater low. Where bulkheads are present, groundwater may discharge below the barrier.
A groundwater low was identified in the southern portion of the island.	The low covered an extensive area along the islands center into the region under the Tank Farms. Due to the removal of most of the monitoring locations in the island center, the extent of the area contributing to this sewer line is unknown.
Groundwater levels are tidally influenced. In general, monitoring wells near the shoreline show a larger influence than interior wells.	A recent tidal study by Lockheed indicated that in some areas the net groundwater flow direction may be toward the interior of the island.

Monitoring Well Network

The long-term groundwater monitoring well network has three components: 1) compliance wells located near the shoreline, 2) early warning wells located inland of the compliance wells, and 3) S&G-OU1 boundary wells. The monitoring well network is shown on Figure 6-3 (located at the end of this document), and the wells are listed in Table 6-1 (Chapter 6 Tables are located in a separate section at the end of this report). The current monitoring locations are the result of several revisions to the groundwater monitoring plan; the most recent version is referred to as Revision 3 (ENSR 2008c).

Compliance monitoring well screen depths vary depending on whether or not a bulkhead is present and the location of the freshwater/saltwater interface. A pre-installation profile assessment was completed at well locations HI-5, HI-6, HI-9, HI-10, HI-11, and HI-12, to

determine the appropriate well screen interval in areas where information on the bulkhead was unknown and to verify that screened intervals were representative of freshwater emanating from inland areas. Direct-push technology was used to generate a vertical profile of the groundwater conditions by collecting samples every 5 feet. The assessment indicated that the freshwater/saline water interface was at 20 to 30 feet below ground surface (bgs). In addition, a second, shallow, higher salinity zone was found from 9 to 15 feet bgs, indicating tidal mixing influences (RETEC 2005).

The results of the conductivity assessment lead to the replacement of monitoring wells HI-2, HI-6, HI-9, HI-10, HI-12, and FW-1 with a deeper screen interval. Table 6-2 (Chapter 6 Tables are located in a separate section at the end of this report) shows the conductivity values collected during the profile assessments and the selected screen interval. Following four quarters of sampling these new deeper wells, the long-term groundwater monitoring well network will be finalized.

The groundwater low identified during the RI on the southern half of the island has been associated with utility lines running north to south down the approximate center of the island. EPA has had some concern that potentially contaminated groundwater will also preferentially follow the backfill of the utilities and discharge to waterway. For this reason, a report on the location and integrity of the utility lines on the island was provided in the Revision 3 Groundwater Monitoring Plan (ENSR 2008c). Due to the age and reported leakage rates into the utilities, groundwater infiltration into the utilities was determined to be highly likely. To monitor the quality of groundwater discharging into the sewer lines or the backfill, two monitoring wells (HI-17 and HI-18) were installed along the sanitary sewer line in the southern portion of the island near the groundwater low identified during the RI as required in the Revision 3 groundwater monitoring plan.

Long-Term Monitoring Analytical Data

The long-term groundwater sampling schedule is presented in Table 6-1 (Chapter 6 Tables are located in a separate section at the end of this report). Existing monitoring wells were sampled on a quarterly basis from September 2005 through September 2007; sampling at these wells is currently on a semi-annual basis. Samples are analyzed for benzene, total and available cyanide, and metals (total arsenic, cadmium, copper, lead, mercury, nickel, silver, thallium, and zinc). The reductive precipitation method (Method 1640) is used to prepare groundwater samples for metals analysis when the water is brackish, or when conductivities are greater than 2 millisiemens/centimeter (mS/cm). PCBs and VOCs other than benzene were removed from the analysis after they were not detected during the first year (four quarters of sampling).

The five new replacement Revision 3 wells and two new interior wells are to be sampled quarterly for one year. The first round of quarterly sampling for the new/replacement wells was completed in June 2009. During this time period, the shallower wells that were replaced by deeper wells will not be sampled. Following the first year of sampling, one of the wells (shallow or deep) will be selected for long-term monitoring. The two new wells in the interior of the island will also be sampled quarterly for one year. If concentrations are below cleanup goals, then sampling of these two wells will cease. All new monitoring wells will be analyzed for metals, cyanide, and selected VOCs (carbon tetrachloride, benzene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, and tetrachloroethene). If VOCs are not detected during the first year, they will be dropped from the analyte list.

Analytical data for the S&G-OU1 long-term monitoring network collected during the last 5 years is presented in Table 6-3 (Chapter 6 Tables are located in a separate section at the end of this report). A brief summary of the data is as follows:

- The maximum benzene concentration was 1.4 µg/L and detected at HI-16, which is well below the cleanup goal of 71 µg/L. PCBs; 1,1,1-TCA; 1,1,2-TCA; carbon tetrachloride; and PCE have not been detected.
- With the exception of HI-17 (see below), arsenic, cadmium, lead, silver, and thallium have not been detected at concentrations above their respective cleanup goals. Nickel has not been detected above the cleanup goal since June 2006 and copper has not been detected above the cleanup goal since December 2007.
- Concentrations of total zinc have historically been detected above the cleanup goal at monitoring wells FW-1, HI-12, MW-1, and MW-213. Dissolved zinc concentrations have been below the cleanup goal. Figure 6-4 (located at the end of this document) presents the concentrations of total zinc concentrations at each well. Replacement wells installed in 2009 for FW-1 and HI-12 did not contain concentrations of zinc above cleanup goals. MW-1 and MW-213 are compliance wells located near the ongoing LNAPL remediation at Todd Shipyards and likely represent impacts from this area.
- Concentrations of total mercury were historically detected above the cleanup goal at monitoring wells FW-1 and HI-6. Dissolved concentrations of mercury have been below the cleanup goal. Replacement wells installed in 2009 for FW-1 and HI-12 did not contain concentrations of mercury above cleanup goals. Upward trends in mercury concentrations were noted in the 2008/2009 monitoring report (AECOM 2009c) at wells HI-7 and HI-9; however, the concentrations are an order of magnitude below the cleanup level.

Monitoring well HI-17 was installed in 2009 near the sanitary sewer line in the center of the island. Concentrations of arsenic, cadmium, lead, nickel, and zinc were detected above ROD cleanup goals. HI-17 is located near the historical groundwater low in the southern portion of the island where water is thought to flow toward the sanitary sewer system and not outward toward the waterways. The well is also located near the former secondary smelter where elevated metals concentrations were detected during the RI. Since groundwater flow has not been evaluated since the RI in the 1990s, an additional groundwater flow assessment should be completed to confirm that groundwater near HI-17 is contained on the island. This assessment may need to include a tidal study.

Figure 6-5 (located at the end of this document) shows the concentration of cyanide at the site. Total cyanide has been consistently detected at monitoring wells HI-1, HI-7, HI-10, and HI-14, and sporadically at monitoring wells HI-2, HI-8, HI-9, HI-11, HI-13, HI-15, HI-16, and FW-1 at concentrations ranging from 1.15 to 345 µg/L. It should be noted that the reporting limit for total cyanide is 5 µg/L, which is higher than the ROD cleanup goal of 1 µg/L. Starting in December 2006, cyanide was also analyzed using the available cyanide method, which has a reporting limit of 2 µg/L and measures both free and weak acid dissociable (WAD) cyanide. The available cyanide method provides a better approximation of the more toxic free cyanide than the total cyanide analytical method. Available cyanide was detected just above the reporting limit at monitoring wells AC-06A, HI-3, HI-16, HI-12, and HI-5 and at concentrations ranging from non-detect to 170 µg/L at Well FW-1. It has not been detected above the reporting limit of 2 µg/L during the last two rounds of sampling. Total cyanide concentrations indicate cyanide may be migrating into the waterway; however, it is not in the more toxic free cyanide form. The S&G-OU1 Steering Committee has requested that total cyanide be removed from the analytical list; however, EPA has no approved the request. A determination on the appropriate cyanide analysis method and the potential to impact the waterway should be completed.

Five-Year Review Sampling Event

As part of the Five-Year Review, EPA requested sampling of all monitoring wells at S&G-OU1 and analysis for the full list of COCs identified in the ROD. In addition, VOCs, semivolatile organic compounds (SVOCs), and additional metals (antimony and chromium) were analyzed at the point of compliance wells to determine if the remedy is functioning as intended. EPA requested that the sampling be conducted during a period of low tides to confirm that the samples are representative of fresh groundwater emanating from the interior of the island.

Table 6-4 (Chapter 6 Tables are located in a separate section at the end of this report) presents the results of the Five-Year Review sampling event. COCs were compared to the cleanup goals presented in the 1993 ROD. All additional constituents were compared to National Recommended Water Quality Criteria (NRWQC) for marine acute and chronic exposures and for human consumption of organisms. Generally, the results of the low-tide sampling event show detected concentrations of constituents are slightly higher than those historically detected. This indicates that there could be a relationship between the tidal cycle and constituent concentration that future sampling events should take into consideration.

A brief summary of the results follows.

- Several metals and cyanide were detected above the ROD cleanup goals. These detections are consistent with concentrations historically observed. Copper was detected above the ROD cleanup goal at monitoring well FW-1, which is located in the Todd Shipyard area. This well is near an active petroleum remediation system, which likely alters geochemical conditions in groundwater and increases solubility of heavy metals. Concentrations of copper in HI-10 and concentrations of mercury in HI-6 slightly exceeded the ROD cleanup goals. This is consistent with concentrations historically observed. Concentrations of arsenic, cadmium, lead, nickel, and zinc at monitoring well HI-17 were also observed above ROD cleanup goals. This is consistent with previously detected concentrations as discussed above.
- PCE, a ROD constituent, was detected at a concentration of 1.7 µg/L at HI-7. Although this concentration is below the ROD cleanup goal of 8.8 µg/L, the well is near the LU-OU3 boundary where PCE has been detected in several monitoring wells (See Section 6.4.2). If the groundwater flow direction in this area is inland, then HI-7 is directly downgradient from this PCE contaminated area. Therefore, future sampling events should include PCE at HI-7 to monitor potential on-site migration.
- Of the additional constituents requested as part of the Five-Year Review sampling event, only one was found above NRWQC values. Bis(2-ethylhexyl)phthalate was detected at HI-5 at a concentration of 7.3 µg/L, which slightly exceeds the NRWQC of 2.2 µg/L. This analyte should be included in future sampling events to determine if it represents a potential remedy problem.

6.2.3 Site Inspection

No site inspection was conducted.

6.2.4 Site Interview

No interviews were performed.

6.3 TANK FARMS OPERABLE UNIT (TF-OU2)

6.3.1 Document Review

This Five-Year Review consisted of a review of relevant documents as summarized in the References section at the end of this report. Documents can be reviewed at the Washington State Department of Ecology, Northwest Regional Office. Applicable groundwater and surface water cleanup standards were also reviewed. All information was provided by the Washington State Department of Ecology who is the lead regulatory agency for the site.

6.3.2 Data Review

Institutional Controls. As part of the remedial action for each facility, restrictive covenants were required to be filed with King County. The covenants were to follow the Model Toxics Control Act Cleanup Regulations and identify the contamination that existed at each facility, provide for continued industrial use of the property, prohibit groundwater taken from the property, provide for safety and notification of site workers, prohibit activities that would release or cause exposure to contamination, provide for continuance of remedial actions given property transference, and provide for Ecology access.

All three facilities' restrictive covenants are on file with King County. Since contamination remains at each of these facilities, the objectives of the covenants are still applicable.

In-Situ Remedial Systems

Design and construction of an air sparging and SVE system was completed along the western property boundary of A Yard in the KM facility during 2006. The KM system is shown on Figure 6-6 (located at the end of this document). The purpose of this remedial system was to function as a bio-sparge barrier to prevent migration of petroleum contamination in groundwater outside property boundaries. It is a requirement in the CAP for this facility to install a barrier to prevent off-property migration of contamination in groundwater at this location. The system consists of five air sparging wells spaced along a 250-foot section of the property boundary installed to approximately 15 feet below ground surface. Trenches with horizontal soil-vapor extraction piping were constructed coincident with the sparge wells. The system has operated continuously since December 2006.

Design and construction of an SVE system was completed as a contingency action along the southern property boundary of Plant 1 in the BP facility during 2007 and 2008. The BP system is shown on Figure 6-7 (located at the end of this document). Installation of this system was initially prompted by stable contaminant levels persisting above standards in a "sentry" monitoring well (AR-03). It is a requirement in the CAPs for the facilities that contingency actions be taken in situations that could affect timely achievement of cleanup standards. Twelve borings were completed to further characterize contamination in the area. A previously-unidentified area of weathered hydrocarbon soil contamination from historic spills was discovered. Four additional monitoring wells were subsequently installed. The identified area of contaminated soil was not accessible for excavation and in situ treatment was required. The SVE system consists of ten horizontal extraction wells located in parallel trenches extending for about 240 feet along the property boundary. The system was built with the capacity to include air sparging if required, and has operated continuously since October 2008.

During 2002, an extensive remediation system was constructed in the BP facility's Plant 1 along the shoreline of the West Waterway. (The BP Plant 1 system is shown on Figure 6-8 [located at the end of this document]). The system was designed to remediate a large area of inaccessible soil, free product, and groundwater contamination behind the bulkhead and beneath a warehouse and loading rack. It also provided hydraulic control to prevent sheen and

contaminated groundwater from entering surface water. The system includes 10 product/ groundwater recovery wells, 12 sparge wells, and 22 horizontal vapor recovery wells. Operation of the system began in early 2003 and it continues to operate at present. The air sparging component was altered to operate in a rapid on-off pulsed mode to increase groundwater movement and enhance oxygen dissolution. Two sparge wells were added to the system for two years in an attempt to address benzene levels above the standard (71 ppb) in a nearby compliance monitoring well (AMW-01). All air sparging and SVE components of the system were discontinued during 2008 because performance data from the system indicated the bulk of available hydrocarbons had been recovered and that continued operation of these components was no longer beneficial. Benzene concentrations remain elevated at two monitoring wells adjacent to the shoreline. Capture zone analyses performed during the remedial system design indicate that the hydraulic containment was met. Since concentrations remain elevated, it is uncertain if hydraulic containment is currently maintained. Additional data analysis should be performed and the system modified as necessary.

Passive product recovery (absorbent socks) was completed in six wells, where measureable free product occasionally occurred.

Natural Attenuation

As previously described, subsurface TPH "hot spots" in two separate areas (Shoreline Manifold Area at Shell and A Yard at KM) had previously been identified above applicable total TPH soil standards during RI work during the mid 1990s and were re-sampled in 2009. Total TPH levels were significantly reduced in both areas, which is direct evidence that natural attenuation is taking place. Data from wells throughout the Tank Farms OU indicate hydrocarbon concentrations are stable or declining, which is also evidence that ongoing natural attenuation is actively reducing the hydrocarbon mass. Geochemical parameter data indicative of natural attenuation (DO, nitrate, dissolved iron, sulfate, methane) were analyzed in select wells at the KM facility. The analyses indicated both aerobic and anaerobic biodegradation are occurring, and that the complete range of degradation processes have been and are active at the site.

Groundwater Monitoring

Groundwater data is provided quarterly from each facility. Figure 6-9 (located at the end of this document) shows the location of monitoring wells at TF-OU2. The Groundwater Compliance Monitoring Plans included within the CAPs for each facility provide for reducing monitoring requirements given declining contaminant levels. Based on long-term data, the numbers of analytes and the sampling frequency have been reduced in many select wells throughout the Tank Farms OU.

Groundwater elevation measurements were historically collected quarterly and groundwater flow maps produced for each separate facility. In general, an area of higher groundwater elevation coincides with the unpaved areas within the BP, Shell, and Kinder Morgan facilities, where most of the large bulk fuel storage tanks are located. Shallow groundwater flows radially outward from the area of higher elevations. Groundwater flow maps produced quarterly over many years for the individual facilities have shown minor seasonal variations within the facilities, but that the overall groundwater flow pattern within TF-OU2 is very consistent.

Since the quarterly groundwater flow maps are no longer produced, a combined groundwater flow map for the entire Tank Farms OU was produced using elevations acquired during November 2009 from wells within each facility. The new map showed that groundwater flow in the north-central part of Harbor Island is generally the same as was indicated in a map produced during the early 1990s. This recent groundwater flow map is presented in Figure 6-10.

A summary of groundwater data collected since 2005 is presented in Tables 6-5 through 6-8 (Chapter 6 Tables are located in a separate section at the end of this report). Monitoring wells are analyzed for TPH-G,-D,-O (gasoline, diesel, oil range), BTEX, cPAHS, arsenic and lead. CPAHs are currently only sampled for in compliance wells screened below bulkheads in the two shoreline areas. Figures 6-11 through 6-14 (located at the end of this document) show the monitoring wells located at each facility. A brief summary of the water quality at TF-OU2 is as follows:

- BP Plant 1 (Figure 6-11):
  - Monitoring well GM-18S was installed in the northeast part of the property as part of the RI. The well has not been monitored and apparently no contamination was identified in the northern area of BP's Plant 1. There is no indication that groundwater contamination interior to Plant 1 migrates towards the northern area.
  - Monitoring wells GM-15S and GM-16S are long-established wells and have been below applicable cleanup levels for many years.
  - MW-3-T9, MW-4-T9, and MW-1-T9 are newer wells monitored since 2006. Data from these wells indicates contaminant levels below applicable cleanup levels since then.
  - Monitoring well AR-03 is located near the southern property boundary of BP's Plant 1. Levels of TPH-G and benzene slightly exceed applicable cleanup standards on occasion. A soil-vapor-extraction system operates immediately upgradient from this well, and contaminant levels appear to be declining.
  - The western boundary of TF-OU2 is a 700-foot area adjacent to the West Water Way at BP's Plant 1. Monitoring wells near the shoreline in this area include AMW-05, AMW-04, AMW-03, AMW-02, and AMW-01. These wells are screened below the bulkhead structures to monitor groundwater flowing beneath to surface water. The cleanup level for benzene has been exceeded in AMW-01 since 2005 and in AMW-02 since 2007. These wells are the southernmost wells along the bulkhead. Average benzene levels since September 2005 are 280 µg/L (AMW-01) and 92 µg/L (AMW-02). The data are variable, but appear to be generally stable with no observed increase. Contaminant levels in the other three shoreline wells (AMW-03, AMW-04, and AMW-05) have been below cleanup levels for many years.
  - As described above, stable but persistent levels of benzene above the cleanup level persist in two compliance monitoring wells, AMW-01 and AMW-02. An investigation was completed to determine a possible localized source of benzene affecting these wells but a source was not found. Two additional air sparge wells were added to the remediation system proximate to these wells, but this had little effect on the benzene levels.
  - It is uncertain if the groundwater recovery component of the remediation system at the bulkhead area continues to operate optimally as per the capture zone analyses conducted during the Engineering Design. The only known source of benzene is in the area of the operating soil vapor extraction (SVE) system to the southeast. Additional data analysis or investigation should be performed and the system modified as necessary.

- BP Plant 2 (Figure 6-12):
  - Monitoring wells GM-20S, GM-21S, GM-22S, GM-23S, and MW-03R were installed as confirmation monitoring wells after extensive excavation and removal of TPH-contaminated soil in Plant 2 during 2000. Monitoring was discontinued in these wells during 2003–2004 after many quarters of sampling results indicated petroleum constituents were and remained below cleanup levels.
  - Monitoring well GM-20S was installed as part of the RI and indicated that contamination was not present in the northwest area of Plant 2. GM-20S was not monitored after the RI; however, data from KM interior wells south of Plant 2 are below cleanup levels indicating there is no impact to Plant 2 from the south.
  - An interior monitoring well, GM-19S, at the southern extent of Plant 2 was impacted by an unknown off-property release during 2000. This interior well currently exceeds the cleanup level for benzene, but the level is declining.
- Kinder Morgan (Figure 6-13):
  - Monitoring wells along the eastern boundary, MW-1, SH-02R, MW-13R, MW-4, MW-12R, MW-07R, and SH-05R, contain petroleum constituents that have been below cleanup levels for 5 years or longer. Total lead levels slightly above the cleanup level are exceeded occasionally in some of these wells.
  - Monitoring wells A-28R, MW-24, and MW23 are proximate to each other near the intersection of 13th Avenue SW and SW Lander Street on the southwest property line of A Yard. Contaminant levels for TPH-G and benzene are stable, but have persisted above cleanup levels during 2005–2010. Contaminant levels in Monitoring well A-23R (near MW-23) have been below appropriate cleanup levels since 2007. An air-sparge\SVE system operates in the near vicinity upgradient from these wells (excepting A-28R).
  - Well MW-21 is located on the southeastern boundary of B Yard near remaining inaccessible soil at a former TPH "hot spot." Contaminant levels have been below applicable cleanup levels in this well since 2006.
  - Monitoring wells A-21, A-14R, A-10, MW-25, and A-8 are along the southern and southeastern boundaries of A Yard and have been below applicable cleanup levels for many years.
  - Four additional monitoring wells were installed in C Yard in the Kinder Morgan facility to augment the existing well coverage in this area. During 1996, a 48,000-gallon gasoline spill occurred in C Yard. Interim actions during 1996 and 1997 addressed the bulk of the spill, but remnant contamination was subsequently addressed in the CAP for this facility. Even though this area is inland, the total TPH soil cleanup standard was established at 10,000 ppm (the shoreline area standard). Cleanup actions were implemented prior to 2005 and included excavation of seven areas of subsurface soil above 10,000 ppm TPH, and the operation of an air-sparging system throughout the yard for 2 years. The new wells were installed to confirm the long-term effectiveness of the cleanup action for the spill. Analytical data from all wells in C Yard indicated contaminant levels in groundwater throughout the yard are below groundwater cleanup levels.

- Shell Main Terminal/Tank Farm (Figure 6-14):
  - Monitoring wells TES-MW-1, MW-101, MW-105, MW-102, MW-111, MW-112, and TX-06 have been below cleanup levels for petroleum constituents and metals for 5 years or longer. MW-105 occasionally exceeds the cleanup level for total lead.
  - TX-03 is located north of and downgradient from the Main Tank Farm, and contaminant levels persist above cleanup levels for total petroleum hydrocarbons as gasoline (TPH-G) and benzene. As a contingency action, five borings were done in the vicinity of the well to investigate. Elevated levels of gasoline contamination in groundwater were found in two borings, but a consistent area of groundwater contamination was not apparent. There was no associated area of subsurface soil contamination. Further evaluation of the data and situation is warranted.
  - Monitoring data from a Sentry Well (SH-04) at the eastern property boundary of Shell's Main Tank Farm demonstrated stable contaminant levels persisting above groundwater standards. As a contingency action, eight borings were done in the vicinity of the well to investigate. An area of gasoline-impacted groundwater was found primarily in 13th Avenue SW (the street separating the Shell and KM facilities). This area of contamination merged with a known area of groundwater contamination in 13th Avenue outside the western boundary of A Yard in the KM facility. Forensic analyses of groundwater contamination within A Yard and in the adjacent street indicated the contamination in the street could be of a different nature. An additional monitoring well was installed and confirmed that contaminant levels were above standards in the street. There are large fuel pipelines beneath the street, but the nature of the contamination does not indicate an ongoing source. There was no area of subsurface soil contamination found associated with the area groundwater contamination. The source of the contamination in 13th Avenue is unknown, and further evaluation of this area is warranted.
- Shell North Tank Farm Area (Figure 6-14):
  - Contaminant levels in monitoring wells MW-201, MW-203, MNW204 have been below applicable cleanup levels since 2007.
  - Monitoring well MW-202 is in the southern interior of the North Tank Farm Area. Contaminant levels for TPH-G above cleanup levels persist in this well.
- Shell Shoreline Manifold Area (Figure 6-14):
  - This area includes a 200-foot shoreline area along Elliot Bay. Two monitoring wells in this area (Wells MW-213 and MW-214) are screened as appropriate below a bulkhead to monitor groundwater flow beneath to surface water. Contaminant levels in these wells have been below applicable cleanup levels for many years.

6.3.3 Site Inspection

No site inspection for this Five-Year Review was conducted.

6.3.4 Site Interview

No interviews for this Five-Year Review were performed.

6.4 LOCKHEED UPLAND OPERABLE UNIT (LU-OU3)

6.4.1 Document Review

This Five-Year Review consisted of a review of relevant documents as summarized in the References at the end of this report. Documents can be reviewed at EPA Region 10 Superfund Records Center. Applicable groundwater and surface water cleanup standards were also reviewed.

6.4.2 Data Review

Institutional Controls. The objectives of the ICs required in the ROD were to 1) warn future property owners of remaining contamination under capped areas on their property, 2) require future owners and operators to maintain these caps, and 3) specify procedures for handling and disposal of excavated contaminated soil in future excavation is necessary.

A review of ICs associated with the LU-OU3 was conducted by Tetra Tech, Inc., the consultant for Lockheed Martin Corporation. The purpose of this review was to ensure that ICs are appropriate, in place, and are effective across the site. The following information was requested by EPA:

1. Documentation of all IC controls in place for the LU-OU3.
2. Copies of all instruments that conveyed any interest in any portion of the LU-OU3 since 15 days of entry of the Consent Decree, with the required provision of access and necessary restrictions or covenants.
3. Figures showing parcel boundaries and survey information.
4. Current information about all lessees or users of the LU-OU3.
5. An ICS that must provide, at a minimum, a title search; copies of encumbrances; evaluation of whether encumbrances negatively impact existing controls; evaluation of compliance with ICs; evaluation of any current human or potential human or ecological exposures; evaluation of any threatened or existing inconsistencies that could lead to exposures; evaluation of the protectiveness and effectiveness of all ICs; evaluation of all instruments, any proposed additional controls; certification that each CD and all other instruments were properly recorded; certification that all property transfer deeds contain obligation to provide access and maintain ICs and require all future transfers to do so; and recommendations.

EPA is currently in the process of reviewing the above data. An initial evaluation of the submitted documentation indicates the objectives are still appropriate. Potential issues with the existing ICs include: 1) proper conveyances may not have been completed for the lease agreement for the ARCO property and 2) the future integrity of the cap is dependent on the Port of Seattle completing the Terminal 10 Utility Infrastructure Upgrade Project (discussed below). In addition, EPA noted several deficiencies in the documentation and requested the following in a letter dated February 12, 2010:

- Consider establishing a restrictive covenant under the recently enacted Washington variation of the Uniform Environmental Covenant Act (UECA). This would obligate all future property interests and give EPA direct enforcement rights to prohibit excavation without written EPA approval.
- Provide further justification to support the ICS memo statement that there are no exposures.

Cap Inspections and Maintenance. The Port of Seattle is responsible for maintaining the integrity of the cap.

Problems with ponded water, asphalt cracks, and plant growth through cracks are frequently reported at the LU-OU3. The ponded water also limits the access to two of the monitoring wells, LMW3 and LMW25.

Inspection reports for 2006 and 2007 cited numerous cracks in the asphalt and concrete at Cap Area 2. Subsequently in 2008, an Interim Maintenance Plan for Terminal 10 (Windward Environmental 2008) was developed to repair these problems and support routine maintenance of the cap areas. The following criteria are currently used for determining required maintenance:

Observed Asphalt Cap Condition	Required Repair Action
Cracks over a 5-square-foot area and observed to be penetrating the cap cross section and causing asphalt breakage or exfoliation.	Crack cleaning and sealing or, if not feasible, asphalt section replacement (paving).
Series of parallel cracks >2 feet long; i.e., indicative of slumping and pavement separation on sloped areas.	Crack cleaning and sealing or section replacement.
Cracks >1/8-inch wide and not penetrating the cap cross section. No plant growth present.	No action. Continue to monitor.
Cracks >1/8-inch wide and determined to penetrate the cap cross section or providing a substrate for plant/weed growth.	Crack cleaning and sealing (routing not required).

All of the cap repairs were complete by the summer of 2008. The July 2008 annual cap inspection noted that the repairs were complete with the exception of sediment that had accumulated in previously pooled areas of the site. The Port of Seattle performed some additional repairs/maintenance to resolve this and other issues identified in the July 2008 report. The cap inspection completed in 2009 recommended plant growth be removed and asphalt cracks be patched. These repairs are to be completed prior to the 2010 inspection.

The repairs described above did not address the larger problem of ponded water at the site. This ponded water may increase the potential for infiltration and mobilization of soil contamination. Completion of the Port of Seattle's Terminal 10 Utility Infrastructure Upgrade Project, which would upgrade the existing storm water system, proposed redevelopment and cap improvements, which includes stormwater controls, is necessary to ensure the future integrity of the cap and protect ecological receptors in the waterway.

Long-Term Groundwater Monitoring

Figure 4-3 shows the monitoring wells at the LU-OU3. Eleven monitoring wells were originally included in the program and are listed in Table 6-9 (Chapter 6 Tables are located in a separate section at the end of this report). Chemical analyses are specific to the impacted area and are also listed in Table 6-9.

Due to construction and remediation activities at the site, several of the original wells in the monitoring well network have been damaged and subsequently decommissioned or removed (LMW4, LMW10, and LMW-15). In addition, monitoring wells LMW3 and LMW25, located in the central portion of the site are periodically inaccessible due to standing water.

In 2005 and 2006, nine new monitoring wells were installed at the site to address source control for the LSS-OU7. Six of the wells are located adjacent to the existing bulkhead (LMW30, LMW31, LMW32S, LMW32D, LMW33, and LMW34) and three wells are located along the eastern edge of the property (BG-01, BG-02, and BG-03). Reporting for the two groundwater monitoring programs is currently provided under separate cover, and each has separate objectives. Lockheed proposed consolidation of the monitoring programs in 2007; however, the plan was never approved. The following groundwater issues should be addressed prior to the programs consolidation:

- A tidal study was completed in 2006 following the installation of the new 40-foot-deep bulkhead wall. The tidal study concluded the net groundwater flow direction was away from the West Waterway. All wells showed a tidal response including those located over 300 feet inland. Wells located along the shoreline below the bulkhead (LMW32D) and south of the bulkhead (LMW30) showed a larger tidal response than those directly behind the bulkhead. The results of the tidal study indicate that the bulkhead may be influencing the direction of groundwater flow. The groundwater flow direction and influence of the bulkhead should be verified prior to consolidating the monitoring programs.
- An evaluation of the conductivity/total dissolved solids was used to determine if monitoring wells are appropriately screened (Lockheed Martin Corporation 2008a). It was determined that wells in the original network, LMW3, LMW7, and LMW18, are screened in freshwater, and LMW9, LMW12, LMW27, and LMW26 are screened in slightly brackish water. Monitoring wells installed as part of the LSS-OU7 behind the bulkhead showed conductivity/total dissolved solids ranging from slightly brackish to slightly saline. One deep well (LMW-32D) was installed below the bulkhead and shows salinity values typical of saltwater. Lockheed concluded that the well screens were appropriate; however, EPA has not concurred.
- The LU-OU3 and LSS-OU7 have different groundwater monitoring objectives. The objective of the LU-OU3 monitoring program is to monitor contaminants at and downgradient of the source area. A shallow well screen interval may be appropriate for this objective regardless of the salinity present in the well. The objective of the LSS-OU7 monitoring program is to demonstrate source control so that the sediment cap will not be re-contaminated. Monitoring wells for this purpose should be designed to intercept groundwater that is discharging to the waterway. At other areas around the island, monitoring wells are screened below bulkheads. At the LU-OU3, the new bulkhead is 40 feet deep and wells screened below the bulkhead will likely be within the saltwater zone (e.g., LMW-32D screened from 40 to 55 feet bgs) and not indicative of freshwater emanating from inland areas. An evaluation of the well screen location necessary to meet each objective should be completed.
- Monitoring wells LMW3 and LMW25 are frequently inaccessible due to standing water. The Port of Seattle is currently designing a Utility Infrastructure Upgrade Project which will mitigate problems with standing water. Following completion of this project, monitoring well requirements for remaining source areas should be re-assessed.

Five-Year Review Sampling Event

As part of the Five-Year Review, EPA has requested that all monitoring wells at the LU-OU3 are sampled for a comprehensive list of analytes including VOCs, SVOCs, chlorinated pesticides, PCBs, TPH, metals, and cyanide. EPA requested that the sampling be conducted during a period of low tides to confirm that the samples are representative of fresh groundwater emanating from the interior of the island.

Table 6-10 (Chapter 6 Tables are located in a separate section at the end of this report) presents the results of the Five-Year Review comprehensive sampling event. COCs were compared to the cleanup goals presented in the 1994 ROD and the NRWQC for marine and chronic exposures and for human consumption of organisms. A brief summary of the results follows:

- LMW25 was not sampled because it was inaccessible.
- Arsenic, copper, nickel, zinc, bis(2-ethylhexl)phthalate, and PCE were detected above screening levels or ROD cleanup goals.
- Several pesticides (4,4′-DDD; 4,4′-DDE; dieldrin; and heptachlor epoxide) were detected at estimatible quantities.

The current analyte list for the groundwater monitoring program at the LU-OU3 is based on COCs historically identified in impacted areas. The results of the Five-Year Review sampling event indicate that the area specific analyte lists may be not adequate. For example, copper, nickel, and zinc were detected at elevated concentrations at LMW27 where only VOCs are analyzed for the long-term monitoring program. Therefore, the groundwater monitoring analyte list for each well and remaining source should be re-evaluated to ensure the remedy remains protective.

Long-Term Monitoring Analytical Data

The analytical data for the LU-OU3 long-term groundwater monitoring is presented in Table 6-11 (Chapter 6 Tables are located in a separate section at the end of this report). The analytes for each well are listed in Table 6-10. As discussed above, the net groundwater flow direction could be inland rather than radially outward as described in the RI. Therefore, the following summary assumes that groundwater flow could occur either toward or away from the West Waterway. Results from the LSS-OU7 groundwater monitoring program are also considered as they relate to source area constituents.

- Benzene has not been detected above the cleanup goal of 71 µg/L since April 1999.
- Lead was detected once above the cleanup level of 5.8 µg/L at a concentration of 7.39 (total lead) in the last 5 years at monitoring well LMW18.
- Zinc was detected once above the cleanup level of 76.6 µg/L at monitoring wells LMW3 and LMW25. The maximum concentration detected was 373 µg/L (dissolved zinc). It should be noted that LMW25 was inaccessible for all but two sampling events during the last 5 years.

- PCE was detected above the cleanup level of 8.8 µg/L in the last five years at monitoring well LMW3. PCE appeared to be decreasing; however, the Five-Year Review sampling event in March 2010 detected it just above the cleanup goal. Figure 6-15 (located at the end of this document) shows the PCE concentrations over time at impacted area well LMW3 and potential down-gradient wells LMW25 (groundwater flow toward waterway) and BG-02 (groundwater flow away from waterway). LMW25 has not detected PCE in the last five years and BG-02 has consistently detected PCE, but at low concentrations. The data indicate that although PCE contamination remains near LMW3, it has not migrated away from the source.
- PCE was detected above the cleanup level of 8.8 µg/L in the last five years at monitoring wells LMW12, LMW27, and LMW26. These wells are located along a transect at the northern portion of the site. Figure 6-16 (located at the end of this document) shows the PCE concentration over time at these wells along with potential down-gradient well LMW9 (away from waterway). LMW12, LMW27, and LMW26 all have had an increasing trend since 2002. There is also an indication of seasonal influence since concentrations in April (wet season) tend to be much higher than in October (dry season). The 2006 tidal study indicated that groundwater flow is inland. Confirmation of the groundwater flow direction is necessary to determine if PCE has the potential to impact the waterway. Additional evaluation of the source may also be required.
- Copper was detected above the cleanup level of 2.9 µg/L in the last five years at monitoring wells LMW3 and LMW25. Figure 6-17 (located at the end of this document) shows the concentrations of total copper over time at impacted area well LMW3 and potential down-gradient wells LMW25 (groundwater flow toward waterway) and BG-02 (groundwater flow away from waterway). The data do not indicate any trends; however, wells LMW3 and LMW25 are frequently inaccessible.
- Copper was detected above the cleanup level of 2.9 µg/L in the last five years at monitoring well LMW18. Figure 6-18 (located at the end of this document) shows the concentrations of copper over time at the impacted area well LMW18 and the potential down-gradient well LMW15 (groundwater flow toward the waterway), which was abandoned in 2003. LMW7 is a potential down-gradient well if groundwater flows away from the waterway; however, copper is not analyzed at this well. Due to this lack of down-gradient data, it cannot be determined if contaminants have migrated from the impacted areas.

6.4.3 Site Inspection

An inspection of the site was conducted on March 4, 2010, by the EPA RPM, Ravi Sanga, and USACE reviewer, Sharon Gelinas. Site photographs are presented in Appendix A. The purpose of the inspection was to observe the condition of the capped areas.

Hay bales were observed at the boundary of the LU-OU3 and West Waterway to prevent sediment-laden stormwater flows from entering the waterway. Ponded water was also observed in several areas; however, it was difficult to determine if the water was located over the designated Cap Areas.

6.4.4 Site Interview

No interviews were performed.

6.5 LOCKHEED SHIPYARD SEDIMENT OPERABLE UNIT (LSS-OU7)

6.5.1 Document Review

The remedial action at the LSS-OU7 was completed on February 4, 2005. The OMMP was approved in September 2006. Final post-remedy sampling and survey data was used to serve as a baseline of COC concentrations remaining after remediation against which future monitoring results would be compared. Future monitoring results would be used to determine whether the remedy is functioning as required and/or if the surrounding area is causing or contributing to recontamination of the LSS-OU7. The first OMM activities and results cover the time from establishment of the baseline in March 2005 through August 2006 (Year 1). OMM Reports have been submitted annually. This five-year review includes all post-remedy monitoring through 2009.

The RPM has reviewed the four annual OMM Reports (Years 1 – 4), compared results with baseline results and has determined that no Response Actions are necessary, except for the some replacement plantings for the Riparian Buffer. Additional plantings were installed in the Fall of 2009 to fill the void of small plantings. Even with the absence of the small plantings, the larger shrubs and small trees serve as a cover for birds and provide a buffer area between the industrial area and the Habitat Beach.

6.5.2 Data Review

The RPM reviewed the sediment chemistry and survey data from each annual OMMP report and concluded that no response actions were necessary because the COCs that were detected were below the SQS cleanup numbers designated as cleanup goals in the ROD, and there were no significant elevation changes in the dredged or capped areas of the LSS-OU7. The results of the monitoring events are provided in Table 4-5.

Results from the various monitoring events indicate that the cap is stable, that surface sediments in the Open Channel are below the cleanup numbers, and that fine-grained sediments cannot be located for sampling in the Slope and Beach Area. Observations of the Riparian Buffer indicate that the larger shrubs, such as shore pines and alders appear to be healthy, while the smaller vegetation is absent due to damage by geese. Conclusions based on monitoring events are shown in Table 4-6.

No institutional controls (ICs) were specified in the ROD, subsequent ESDs, or the CD for the LSS-OU7. Specific institutional controls beyond best management practices and review of permit applications through the USACE have not been implemented nor has an Institutional Controls Study been completed.

6.5.3 Site Inspection

The RPM inspected the LSS-OU7 on October 1, 2009, during a low tide and found the site to be consistent with previous inspections.

6.5.4 Site Interview

The RPM met with Glen St. Amant of the Muckleshoot Tribe on January 20, 2010, to discuss whether the Tribe had any concerns or questions regarding the LSS-OU7 cleanup. The Tribe does not have any concerns regarding the protectiveness of the cleanup as completed for ecological risk. Also, Mr. St. Amant agreed that a risk to Tribal fishers and consumers of seafood from the LSS-OU7 area was not a concern because the completed remedy was based on dredging to native material and a containment cap over in-place contaminated sediments. The only detected chemicals (still under levels of concern for ecological risk) are from

deposition of contaminated sediments outside the LSS-OU7. EPA determined that the deposition was from outside the LSS-OU7 because of the nature of the sediments observed during sampling (were finer and fluffier) and the results of the chemical analysis of the deposited material. The area subject to deposition of contaminated sediments is about 5 acres in the open waterway.

6.6 WEST WATERWAY OPERABLE UNIT (WW-OU8)

Since there was no remedial action for the West Waterway OU, a five-year review is not required.

6.7 TODD SHIPYARDS SEDIMENTS OPERABLE UNIT (TSS-OU9)

6.7.1 Document Review

The remedial action at the TSS-OU9 was completed in February 2007. The OMMP was approved in August 2007. Final post-remedy sampling and survey data was used to serve as a baseline (Year 0) against which future monitoring results would be compared. The OMMP Baseline Monitoring Report was submitted to EPA in December 2007. Future monitoring results would be used to determine whether the remedy is functioning as required and/or if the surrounding area is causing or contributing to recontamination of the TSS-OU9. The first OMM activities and results cover the time from establishment of the baseline in October 2007 through October 2008 (Year 1). OMM Reports have been submitted annually. This five-year review includes all post-remedy monitoring through 2009.

The RPM has reviewed the OMMP Baseline Monitoring Report (Year 0) and two annual OMM Reports (Years 1 and 2), compared results with baseline results and has determined that no Response Actions are necessary.

6.7.2 Data Review

The baseline cap integrity monitoring consisted of diver surveys along 17 specified transects in the capped areas. These transects are located at Piers 1, 2P, 3, 4N, 5, and 6 at the over-water area at the building berth. Detailed diver observations and comments (documented on audio/video recordings) were made at 10-foot increments along each transect and included a determination of whether the substrate is a sand cap, or sediment previously capped but uncovered due to erosion or downslope movement of cap material. Two surface samples of in-place cap material were collected from each of the 17 capped area transects using diver cores. These samples were tested to determine grain-size distribution of the cap material for future comparison. The sand cap consisted of medium to coarse sand.

The RPM reviewed the diver visual survey data from the baseline and each annual OMM report and concluded that no additional response actions were necessary because there is no evidence that significant erosion of cap material has occurred. The presence of shell debris and silts indicate that the area has not been subject to erosional forces. Results from the various monitoring events indicate that the cap is stable with build-up of shell debris and/or silts over time.

No ICs were specified in the ROD, subsequent ESDs, or the CD for the TSS-OU9. Specific ICs beyond best management practices and review of permit applications through the USACE have not been implemented; however, Todd submitted information on ICs per EPA's request. EPA has determined that the PRPs need to conduct an Institutional Control Study to specifically identify which Ics are needed and the process for implementing them.

6.7.3 Site Inspection

A site inspection is not necessary because the remedial action, which was comprised of dredging and capping contaminated sediments, is not visible. However, annual monitoring includes diver's video surveys of the capped sediments. Diver observations during these annual inspections are included in the annual OMM report which were reviewed as part of this FYR.

6.7.4 Site Interview

The RPM met with Glen St. Amant of the Muckleshoot Tribe on January 20, 2010, to discuss whether the Tribe had any concerns or questions regarding the TSS-OU9 cleanup. The Tribe does not have any concerns regarding the protectiveness of the cleanup as completed for ecological risk. Also, Mr. St. Amant agreed that a risk to Tribal fishers and consumers of seafood from the TSS-OU9 area was not a concern because the completed remedy was based on dredging to native material or placement of cap over in-place contaminated sediments.

6.8 EAST WATERWAY OPERABLE UNIT (EW-OU10)

Since there was no remedial action for the East Waterway OU, a five-year review is not required.